RULES

Books and periodicals may be used in the Society rooms by members and friends.

Members may borrow books for home use—with the exceptions noted below—but no one shall have more than four books at any time, or keep any book more than two weeks.

Volumes belonging to a set—such as volumes of bound periodicals and of proceedings or transactions of societies—and such other books as the Board of Government may designate, may be taken from the rooms for a limited time only, by special arrangement with the attendant. They shall be subject to recall at any time.

There shall be no immediate renewal of any book on its return to the library.

A member borrowing a book shall at that time give a receipt therefor.

A fine of one cent per day per volume shall be charged for over-time, and must be paid before the delinquent can take any more books.

Hand books, indexes, current numbers or unbound files of periodicals, books belonging to the Clemens Herschel Special Library, and new books not yet placed on the regular shelves must not be taken from the rooms.

Books of unusual value are marked with a star (*), and must not be taken from the rooms, except by written permission from the Librarian, to be filed by the attendant.

Any person mutilating or losing a book shall pay for the damage, or replace the book.

Any one who violates the above rules may, upon written request from the Librarian to the Board of Government, be debarred from the privileges of the library for such time, not less than three months, as the Board of Government may determine.

(Revised June 16, 1915.)

JOURNAL

OF THE

New England Water Works

ASSOCIATION.

VOLUME VIII.

September, 1893 to June, 1894.

PUBLISHED BY

BOARD OF EDITORS.

Junior Editor's Office, New London, Conn.

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NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VIII. September, 1893. No. 1.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

PROCEEDINGS OF THE TWELFTH ANNUAL CONVENTION.

WORCESTER, MASS., June 14, 15, and 16, 1893.

The sessions of the Twelfth Annual Convention of the Association were held in Horticultural Hall, Worcester, Mass., on Wednesday afternoon and evening, June 14, and on Thursday forenoon and evening, June 15. The headquarters of the Association were at the Waldo House, the Bay State House, where the preliminary arrangements for accommodations had been made, having been damaged by fire a few days before the date of the convention.

AFTERNOON SESSION.

WEDNESDAY, June 14, 1893.

President Chace called the convention to order at 3 P.M., and presented His Honor Henry A. Marsh, Mayor of Worcester, who spoke as follows:

ADDRESS OF WELCOME BY MAYOR MARSH.

Mr. President and Members of the New England Water Works Association: It gives me great pleasure in behalf of the citizens of Worcester to welcome you. Worcester, as you know, is called the "heart" of the Commonwealth. We are proud in the knowledge of the fact that it is the second city in the State, and perhaps, as some of you are strangers here, I may say a word about our city. I am often asked why it is that Worcester, being located as it is forty-five miles from tide water, is so prosperous. It has a population to-day of nearly 100,000. The secret of its great prosperity is largely in the fact that its railroad facilities are unsurpassed, five different lines entering the city. Another fact of importance is the wonderful diversity of its mechanical interests, nearly all of which are maintained by resident capital, so that the money that is made in Worcester is spent here. In your drives about the city you will be pleased, I know, with the great number of attractive looking houses you will see, not only of the capitalists,

but of the workingmen of Worcester. Our water-supply is obtained from two independent sources, each of which is in itself ample for the domestic and manufacturing purposes of the city. The quality of the water is of a high standard, far above the average, of purity, and the service for fire purposes is probably unsurpassed by that of any city in New England. You see we have very much to be grateful for, and I wished to say at least so much about our city in opening.

I applaud heartily the objects of an association like yours. Your meetings cannot fail to be pleasant and profitable. They are pleasant in the renewal of friendships and the making of new acquaintances; they are profitable in the opportunity for the interchange of information upon subjects in which you are all interested. In these days of progress and of competition, in these days of great advance in applied sciences, men cannot be too well informed on the branches of industry in which they are engaged. Your association, with its instruction and mutual exchange of ideas and knowledge, does more than anything else I can think of to improve the water works departments of our cities and towns; and we are glad you have chosen to visit us this year.

The committee on the part of the city government have authorized the Water Commissioner and the Registrar to entertain you, and they have arranged a programme which I hope can be carried out to the letter. Messrs. Brady and Batchelder are the two busy B's in our water department; you probably know them well. If they desire any further assistance from either the committee or the Mayor it shall be forthcoming. I am glad the clouds have cleared away, and I hope the sun will shine during your entire visit here, and that you will take with you to your homes none but the pleasantest impressions of our beloved city. (Applause.)

The President called for the regular order of business.

On motion of the Secretary, the reading of the minutes of the last meeting was dispensed with, they having appeared in the printed pages of the Journal.

ELECTION OF MEMBERS.

The Secretary read the following names of applicants for membership, all of whom had been properly endorsed and favorably considered by the Executive Committee:

RESIDENT ACTIVE MEMBERS.

George E. Crowell, proprietor Water Works, Brattleboro', Vt.; Andrew B. Goodier, Treasurer and Superintendent, Southbridge, Mass.; Horace Kingman, Superintendent, Brockton, Mass.; William J. Luther, Superintendent and Registrar, Attleboro', Mass.; George L. Merick, Civil Engineer, Everett, Mass.; Joseph E. Selfe, Water Commissioner, Wellesley Hills, Mass.; F. J. Shepard, Treasurer, Derry, N.H.; John C. Sullivan, Registrar, Holyoke, Mass.

NON-RESIDENT ACTIVE MEMBERS.

B. A. Eardley, Registrar Pacific Improvement Company's Water Works, Pacific Grove, Monterey County, Cal.; William E. Griffith, Secretary Water Commissioners, Cumberland, Md.; W. S. Lea, McGill University, Montreal,

Quebec; Fred H. Pickles, Engineer and Superintendent, Winona, Minn.; William B. Taft, Civil Engineer, Glen's Falls, N.Y.; W. G. Zich, Superintendent, Waterford, N.Y.; A. Prescott Folwell, Civil Engineer, Atlantic Highlands, N.J.

ASSOCIATE MEMBERS.

Neptune Meter Company, "Water Meters," 408 Temple Court Building, New York city; Benjamin C. Smith, Agent French's Pipe Cutting Machine, 275 Pearl street, New York city; Weir Meter Company, "Water Meters," 7 Dodge street, Salem.

On motion of Mr. Philbin, the Secretary was directed to cast the ballot of the Association in favor of the admission of the applicants, and they were declared elected members.

President Chace's annual address was as follows:

ADDRESS OF PRESIDENT CHACE.

Brethren of the New England Water Works Association: It is with deep regret that I have to announce that we have lost one of our number by death since the last meeting. Augustus W. Locke, of North Adams, Mass., died May 14, 1893, at the age of forty-six. He had been a member of this Association since June 13, 1889, and was also a member of the Boston Society of Civil Engineers. He was an able and genial man, much beloved by those who knew him well.

It has been customary for the President, at the Annual Meeting, to give in his address a summary of the work of the Association. But the work of the past year is known to the members through the issues of the JOURNAL, and its growth in numbers and financial resource is shown by the reports of the Secretary and of the Treasurer.

The members know the value of the organization; they know its work. How shall its value become better known to the public at large, and its influence be extended?

The organization began with a meeting of twenty-one water works superintendents and registrars at Young's Hotel, Boston, April 19, 1882.

What is a water works superintendent? What are his duties and qualifications?

The answer to these questions must vary with the population and other conditions of the town or city where the office is located. The smaller the town, the smaller will be the superintendent's salary and the more manifold his duties. He may be obliged to run the pumps, collect the water-rates, lay pipes, keep records, be draftsman, foreman of laborers, steam engineer, civil engineer, and clerk all in one, with a salary not at all commensurate with the extent of his duties. If in a large city, his duty will consist mainly in directing, by due oversight, the work of a body of skilled subordinates in a thorough and efficient administration of the affairs of the water works under his charge.

With this preface, may it not be profitable for a few minutes to attempt to outline the qualifications of an ideal superintendent?

He must, first of all, be self-reliant, not self-conceited. The self-reliant

man knows his own powers and limitations. He will insist, in a dignified manner, upon proper deference and respect to his rightful authority, and inspire confidence in his own ability. At the same time, he will often seek advice from a competent source, and in emergencies and critical cases, while prompt to act, never be hasty, rash, or foolishly obstinate.

The self-conceited man overrates himself and underrates his fellows. He strives to carry out his pet plans, not because they have been carefully considered and are the best, but because they are his.

The superintendent, if able to have a corps of assistants, must know enough of the details of their duties and enough of human nature to be a judge of their fitness to perform the tasks assigned them. He should know how to "*size up*" a man, so as to decide whether, notwithstanding some faults and weak points, he is, on the whole, a success, or on the other hand, whether, although possessing ability and skill, he has some radical defect of character which unfits him for his place and calls for his discharge. The more the superintendent knows of mechanical and civil engineering, the better. He must, at least in a general way, be responsible for the care of much valuable machinery, and, in the growth of cities and towns, much construction work must fall to the lot of water works men. It is important that the superintendent have sufficient engineering skill to give weight to his opinions in regard to all water works construction.

Of even more importance is it that he should have a thorough knowledge of water. There are many experts in steam, civil, and mechanical engineering; many expert chemists and botanists. But the number of men who understand water, the conditions of its purity, the sources of its supply, the causes of contamination, the best methods of distribution, the changes which water undergoes under the varying circumstances of light, heat, soil, air, depth, and contaminating elements, and who, at the same time, can make their fellow-men believe they understand water, this number of men is, at present, small.

Whatever the sciences of geology, botany, chemistry, and bacteriology can teach in regard to the quality of water should be known to the superintendent. He must be a student, a reading man, of practical common-sense, of courage, patience, and perseverance.

Above all else he should be a gentleman, that by his bearing he may win the good will of the public whom he serves, for the highest ability is useless to one who cannot command the support of the community whose confidence is essential to his success. Who among us would claim to possess all the qualities I have described?

Yet, although no one of us reaches the standard here set forth, the New England Water Works Association as a body does possess the ideal superintendent. By our meetings, our JOURNAL, our discussions, our harmonious interchange of thought and experience, we are as one man, the ideas and powers of each welded together into one perfect whole, ready to meet any emergency and to carry forward any enterprise of water works maintenance or construction. At least, if such is not the present actual state of the case, such a condition is attainable from the character of the membership of the Association.

What we most need is to make the strength of which we are ourselves conscious become a living reality to the world at large.

The general public should understand that problems of water-supply which the

ordinary citizen is utterly incapable of solving and upon which his opinions are valueless, it is the business of the members of the New England Water Works Association to study and solve.

In other professions, like that of the teacher and the physician, he who does not belong to any organized body of his fellows is considered behind the times and non-progressive, and is likely to lose professional standing.

It should be understood that the New England water works official who has no connection with this Association, who does not read its JOURNAL, is behind the age and unfitted to administer the affairs of water works.

We should interest the public press to spread before the people more fully than has yet been done the work of this Association.

I have found intelligent citizens who did not even know of its existence.

A body of 412 members, embracing all shades and kinds of water works engineering experience, chemists, botanists, and other scientists, is competent to teach the people many valuable things about water-supplies, and if we may judge by the absurd statements sometimes seen in the daily press, there are few questions of which the common people are more ignorant than upon a question of a proper public water-supply. This shows the need of such societies as ours.

Brethren, if we continue to work together to enlarge our membership, increase our funds, add to our stock of knowledge, and thus increase our usefulness, we have before us as an organized body, a long and prosperous life. (Applause.)

The Secretary then read the following:

ANNUAL REPORT OF THE SECRETARY.

NEW ENGLAND WATER WORKS ASSOCIATION,
OFFICE OF THE SECRETARY,
NEW BEDFORD, MASS., June 1, 1893.

TO THE MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen: Your Secretary herewith presents his report for the year ending May 31, 1893.

On June 1, 1892, the membership of this Association was as follows, viz.:

Active members	290
Honorary members	5
Associate members	70
Total	365

During the year there has been a loss of twenty-four members, from the following stated causes:

Resignations	16
Deceased	2
Suspended for non-payment of dues	4
Declined membership after election	2
	24

Seventy applications for membership have been presented, endorsed by the executive committee, all of which have received favorable action.

One application for reinstatement as an active member has been granted.

The membership at this date is

Active members	338
Honorary members	5
Associate members	69
Total	412

The net gain for the year has been 47 members.

It may be of interest to trace the growth of the Association from the date of its organization. The following statement shows the membership at the end of each Association year.

June 21, 1882	27
" 1, 1883	43
" " 1884	57
" " 1885	127
" " 1886	153
" " 1887	191
" " 1888	238
" " 1889	277
" " 1890	335
" " 1891	360
" " 1892	365
" " 1893	412

Your Secretary has made 530 collections, which may be thus itemized:

Advertisements	$1,400 00
Initiations	317 00
Dues	1,293 00
Sale of badges	86 95
Sale of journals	237 48
	$3,334 43

All of which has been paid to the Treasurer.

Respectfully submitted,

R. C. P. COGGESHALL,
Secretary.

The report was accepted.

Mr. Nevons, Treasurer, submitted the following report:

ANNUAL REPORT OF THE TREASURER.

HIRAM NEVONS, TREASURER, IN ACCOUNT WITH THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Dr.	
1892.		
June	Balance on hand	$1,806 42
	Amounts received from	
" 15	R. C. P. Coggeshall, Secretary	200 00
" 24	" " "	300 00
Nov. 23	" " "	1,300 00
1893.		
Mar. 17	" " "	1,000 00
June 3	" " "	534 43
" 14	Accrued interest to date, Cambridge Savings Bank	29 90
" "	Accrued interest to date, Cambridgeport Savings Bank	160 14
		$5,330 89

	Cr.	
1892.		
June 14	By payment to Hiram Nevons	$15 00
" "	" " Hotel Hamilton	30 45
" 18	" " C. L. Barker	113 25
" 24	" " Bacon & Burpee	67 30
July 13	" " Chas. H. Currier	12 60
" "	" " T. P. Taylor	23 61
Sept. 8	" " Matthews-Northup Co.	18 00
" 30	" " Heliotype Printing Co.	16 00
" "	" " L. C. Smith	2 25
" "	" " W. H. Richards	86 12
Nov. 2	" " Charles F. Irons	184 00
" 21	" " Charles W. Jenks & Bro.	3 00
Dec. 12	" " R. C. P. Coggeshall	250 00
" "	" " " "	152 42
" "	" " Mercury Publishing Co.	129 70
" 15	" " J. R. Whipple & Co.	18 00
" "	" " F. L. Pratt	15 00
" 19	" " J. R. Whipple & Co.	3 00
" 20	" " J. W. Black & Co.	7 60
" "	" " Thomas P. Taylor	11 00
" 23	" " W. H. Richards	99 21
1893.		
Jan. 13	" " Day Publishing Co.	277 25
" "	" " George E. Starr	5 50
" 18	" " J. R. Whipple & Co.	16 00
" 22	" " F. L. Pratt	15 00
	Amount carried forward,	$1,571 26

	Amount brought forward,		$1,571 26
Feb. 13	By payment to Heliotype Printing Co.		18 93
" "	" " " " "		158 25
" "	" " M. N. Baker		5 00
" "	" " J. R. Whipple & Co.		18 60
" "	" " F. L. Pratt		15 00
" 18	" " H. C. Whitcomb & Co.		18 00
" 20	" " Carl J. Viets		1 30
" 24	" " Day Publishing Co.		208 04
" "	" " Heliotype Printing Co.		67 50
Mar. 13	" " J. R. Whipple & Co.		19 50
" "	" " F. L. Pratt		15 00
" 21	" " Heliotype Printing Co.		10 00
" "	" " Bacon & Burpee		60 00
" 24	" " Heliotype Printing Co.		40 00
" "	" " W. H. Richards		110 86
" 31	" " Heliotype Printing Co.		16 50
April 8	" " Day Publishing Co.		297 00
" "	" " Heliotype Printing Co.		17 50
" "	" " C. C. Taylor		6 00
June 6	" " R. C. P. Coggeshall		250 00
" "	" " " "		105 42
" "	" " Edwin Dews		9 00
" "	" " Mercury Publishing Co.		175 00
" 7	" " J. W. Black & Co.		13 40
" 8	" " Forbes Lithograph Manufacturing Co.		43 68
" "	" " " " " "		6 00
" "	" " W. T. Almy		20 48
" 12	" " Hiram Nevons		20 00
			$3,317 22
" 14	Balance on hand National City Bank	$323 63	
	Cambridge Savings Bank	500 00	
	Accrued interest to date	29 90	
	Cambridgeport Savings Bank	1,000 00	
	Accrued interest to date	160 14	
			2,013 67
			$5,330 89

Respectfully submitted,

HIRAM NEVONS, *Treasurer.*

Approved.

A. R. HATHAWAY,
JOHN L. HARRINGTON.

The report of the Treasurer was accepted.

The special committee, continued at last convention to consider the recommendations made by ex-President Noyes at the Hartford convention in regard to permanent headquarters, not being ready to report, the matter was passed.

Mr. FitzGerald, chairman of a special committee appointed to consider the question of "Uniformity in the Preparation of the Annual Report," submitted the following report in behalf of the committee:

REPORT OF COMMITTEE ON STATISTICS IN ANNUAL REPORTS.

At the Springfield convention of June, 1885, Messrs. Billings and Coggeshall, after an exhaustive study of the question of uniformity in annual reports, submitted recommendations as to a form of statistics and suggestions for a model report covering the management, construction, and finances of a water works system.

This excellent report has formed the basis for the tables adopted by many of the cities and towns, not only in New England, but throughout the United States.

All who have occasion to study the annual reports submitted by water boards and others must acknowledge that the information contained in the statistics is more often consulted than any other portions of these official documents. Their great value has been abundantly demonstrated by the eight years which have passed since Messrs. Billings and Coggeshall submitted their suggestions.

Your committee recently appointed to ascertain the best steps to take to secure a more general adoption of the "statistics" have given the subject much thought and have consulted many members of the Association.

All agree as to the desirability of a greater uniformity, and none have been able to suggest improvements in the forms already recommended.

Your committee have come to the conclusion that there is nothing of material value to be added to these forms as outlined in 1885, and that as the principal cities in New England have already largely adopted them, it would be unwise to change the statistics. Among the important municipalities which now use these forms, in whole or in part, are the following:

Boston,	Ware,	Plymouth,	Woonsocket,
Fall River,	Lynn,	Springfield,	New London,
Fitchburg,	New Bedford,	Taunton,	Burlington,
Holyoke,	Newton,	Waltham,	

and among those which have not yet adopted the statistics are the following places:

Brockton,	Hartford,	Meriden,	Salem,
Brookline,	Keene,	Natick,	Waterbury,
Cambridge,	Lawrence,	New Britain,	Whitman,
Clinton,	Lowell,	Pawtucket,	Woburn,
Concord, N.H.,	Malden,	Pittsfield,	Worcester.
Holbrook,	Melrose,	Providence,	

Your commitee recommend that a large edition of Messrs. Billings and Coggeshall's report be reprinted in full in pamphlet form, with covers and an

appropriate title, and that copies be sent to the water boards and other officials throughout the country, accompanied by a few words of earnest appeal in favor of a universal adoption of the forms recommended.

Respectfully submitted,

DESMOND FITZGERALD,
WILLARD KENT.

On motion of Mr. Brackett, the report was accepted and the matter referred to the executive committee with full powers to carry out the recommendations.

Mr. Brackett. This is a subject of sufficient importance to warrant further consideration. I feel a very deep interest in the more general adoption of this plan by the towns and cities of New England than has been heretofore. If all of our members could be impressed with the value of the tables, instead of only 18 cities and towns as now, we should have every member of the Association joining in a work which can be very easily carried out and would be of immense value. The larger the number that adopt the plan, the greater will be the value of the resulting tables. Much of the data included in the form suggested is now given in the different annual reports, but it is scattered about on different pages, and often given in such a way as to be unavailable for comparison with other reports. I think great credit is due to the members of the original committee for the thoroughness with which they did their work, so that after a trial of a number of years no changes are suggested by the committee which has now examined into the question.

In the last number of the Journal you will find a compilation of the statistics of 18 cities and towns for the past 5 years. They will be found not only convenient for reference, but they are worthy a careful perusal.

In compiling these statistics a number of facts have been brought prominently to my attention. One is the large increase in consumption in many cities and towns during the past five years. For instance, the consumption in Burlington, Vt., has risen from 50 to 58 gallons per day for each consumer; Fitchburg, from 84 to 95; Lynn, 49 to 55; Newton, 31 to 49; Taunton, 37 to 46; Waltham, 32 to 47. Those are suggestive figures, and if this continues we must study to find a remedy. I trust that every member will, in the next annual report, follow out the suggestions of the committee and add the 2 or 3 pages giving the statistics in the form which they suggest, so that they can be tabulated and printed in our Journal in a convenient form for reference.

There being no other business to come before the convention, the reading of papers was in order. The first paper was presented by John Thomson, Hydraulic Engineer, New York city, its title being, "Is the Game Worth the Candle?" under which he considered the question of whether it is wise to seek to attain exactness in construction and operation of meters. Mr. Walker and Mr. Brackett were called upon by the President to discuss the paper.

Mr. Nevons presented photographs and explained the operation of a little device of his invention for measuring the thickness of pipe, and the convention then adjourned till 7.30 P.M.

EVENING SESSION.

At the evening session, on motion of Mr. Nevons, seconded by Mr. Walker, the Secretary was directed to send the greetings of the Association to Mr. Hawes, of Fall River, and to express the regret of the members at his inability to be present.

W. E. McClintock, Civil Engineer, Boston, read a paper entitled "Water Pipe Trenches *vs.* Good Roads," illustrated by the stereopticon. Mr. Fuller, Mr. Nevons, Mr. Decker, and Mr. French spoke upon topics suggested by the paper.

Prof. Dwight Porter, of the Massachusetts Institute of Technology, gave a description, illustrated by the stereopticon, of the Hydraulic Laboratory at the Institute.

Adjourned to Thursday, at 9 A.M.

MORNING SESSION.

Thursday, June 15, 1893.

Mr. Holden, chairman of the Nominating Committee, made the following report:

OFFICERS, 1893–94.

PRESIDENT.

George E. Batchelder, Worcester, Mass.

VICE-PRESIDENTS.

Josiah S. Masey, Gardner, Maine; Charles K. Walker, Manchester, N.H.; F. H. Crandall, Burlington, Vt.; George A. Stacy, Marlboro', Mass.; Byron I. Cook, Woonsocket, R.I.; Sherman E. Granniss, New Haven, Conn.

SECRETARY.

R. C. P. Coggeshall, New Bedford, Mass.

TREASURER.

Hiram Nevons, Cambridge, Mass.

SENIOR EDITOR.

Dexter Brackett, Boston, Mass.

JUNIOR EDITOR.

Walter H. Richards, New London, Conn.

EXECUTIVE COMMITTEE.

F. F. Forbes, Brookline, Mass.; A. H. Salisbury, Lawrence, Mass.; P. Kieran, Fall River, Mass.

FINANCE COMMITTEE.

Jno. C. Whitney, Newton, Mass.; T. W. Sawyer, Milford, Mass.; John L. Harrington, Cambridge, Mass.

On motion of Mr. Fuller the report was accepted.

On motion of Mr. Eaton the Secretary was directed to cast the ballot of the Association for the nominees, and they were declared elected officers for the ensuing year.

No communication having been received as to the place where the next annual convention should be held, on motion of the Secretary the subject was referred to the executive committe with power.

Mr. John C. Chase, Engineer and Superintendent, Clarendon Water Co., Wilmington, N.C., presented a paper entitled "An Experience with a Stand-pipe."

The Secretary read a paper prepared by Mr. William R. Hill, Chief Engineer, Syracuse Water Works, Syracuse, N.Y., giving an account of "The location, construction, and laying of a 54-inch steel submerged-pipe in Skaneatles Lake, for the Syracuse Water Works."

Mr. Clemens Herschel gave a summary of his paper on "The Works of the East Jersey Water Company for the Supply of Newark, N.J.," calling attention to the special novel features of the work.

Professor Drown's paper on "Purification of Water by Freezing" was read by Mr. F. P. Stearns.

Mr. Brackett opened the discussion on the topic "Details of Pipe Castings and Coating," and was followed by Mr. Billings, Mr. Noyes, Mr. Allen, and Mr. Fuller. The topic "The Filling of Service Pipes by Sediment or Tuberculation" was discussed by the President, Mr. Noyes, Mr. Fuller, Mr. Brown, Mr. Beals, and Mr. Chase.

The Secretary read the following communication:

WORCESTER, June 14, 1893.

At a meeting of the associate members of the N. E. W. W. Association, Mr. Anthony Smith in the chair, the following resolution was offered and unanimously carried:

Resolved, That the associate members of the N. E. W. W. Association highly appreciating the liberal provision made by the Association of a hall and other conveniences for the display of Water Works supplies and accessories, are duly grateful for the courtesy extended, and hereby tender their most hearty thanks to the Association for the same.

Respectfully submitted,

W. D'H. WASHINGTON,

Secretary.

The convention then adjourned to 7.30 P.M.

EVENING SESSION.

At the evening session Mr. F. W. Dean, of Boston, made an address, illustrated by the stereopticon, on "Recent Practice in Pumping Machinery."

NEW MEMBERS ELECTED.

Joseph L. Kenney, Superintendent, Lewiston, Me., and Frank L. Northrup, Superintendent, Milford, Mass., were elected Resident Active Members.

On motion of Mr. Brackett, the Secretary was directed to extend the thanks of the Association to the city of Worcester, through the Water Department, to the Union Meter Company, and to others who may have, during the sessions, added to the pleasure of the meeting.

Adopted.

The Secretary put the motion that the thanks of the Association be given to the President for the able manner in which he had presided.

Adopted.

The PRESIDENT. I thank you, gentlemen, for your appreciation. I assure you it has been a very agreeable and pleasant duty to preside over your meetings the past year; and if there has been any success on my part it has certainly been due to the very cordial support I have received from the officers and other members of the Association. It now gives me pleasure to present to you the President for the ensuing year. I am sure you can be congratulated upon your choice. The office will be honored by the city of Worcester, by the Water Department of Worcester, and by the man. Gentlemen, I present to you your President, Mr. George E. Batchelder. (Applause.)

President Batchelder then took the chair and said:

Gentlemen of the New England Water Works Association: Accept my thanks for the honor you have conferred upon me to-day by electing me to this office. It certainly is an honor for any man to be chosen to preside over a representative body of men like this. My predecessors in office have set me the example of brevity in speech, which is fortunate for me. I do wish to say, however, that we had thought our plans were almost perfect for one of the best conventions ever held by the Association, but the unfortunate event occurring, over which we of course had no control, completely demoralized us. I know that many of you have been discomforted, and I am very sorry it should have happened so; but I am happy to say that all of you have taken it in good part. Again thanking you for your kindness, the Chair is ready for any motion.

On motion of Mr. Brackett, the convention adjourned.

The social features of the convention were as follows: On Wednesday evening the visiting ladies were tendered a reception by Mrs. George E. Batchelder. On Thursday afternoon, by invitation of the Worcester Water Department, the members and friends enjoyed a ride in barges to various points of interest about the city, including Institute and Elm parks, and an interesting inspection of the works of the Washburn & Mowen Manufacturing Company, the buildings of the Worcester Polytechnic Institute, the works for purification of sewage at Quinsigamond, and the Union Water Meter Company's works. At the latter place a

lunch was served. After returning to the City Hall a trial of eight fire streams from the high service hydrants was witnessed.

On Friday by the courtesy of the Union Water Meter Company, the members and ladies were entertained at Lake Quinsigamond, where several hours were pleasantly spent with games and trips around the Lake. The entertainment terminated with a lunch and clambake, and after remarks by Messrs. Walker and Stacy expressing the appreciation of the Association of the courtesy of the officers of the city and the Union Water Meter Company, which were pleasantly responded to by the Mayor, the party returned to the city.

LIST OF EXHIBITS BY ASSOCIATE MEMBERS AT THE CONVENTION.

Ashton Valve Company, Boston, Mass., Relief Valves.

Coffin Valve Company, Boston, Mass., Valves and Hydrants.

Crosby Steam Gage and Valve Company, Boston, Mass., Hose, Gages, Valves, etc.

Curtis Regulator Company, Boston, Mass., Pressure Regulators and Reducing Valves.

Deane Steam Pump Company, Holyoke, Mass., Photographs of Pumping Machinery.

The Fairbanks Company, Boston, Mass., Valves.

Frost & Adams, Boston, Mass., Draughtsmen's Materials.

Hersey Manufacturing Company, South Boston, Mass., Meters.

The Hydraulic Construction Company, New York city, Driven Well Apparatus.

Henry F. Jenks, Pawtucket, R.I., Drinking Fountains and Pipe Wrench.

H. W. Johns Manufacturing Company, Boston, Mass., Asbestos specialties.

Michigan Brass and Iron Works, Detroit, Mich., Hydrants.

National Meter Company, New York city, Meters.

National Tube Works Company, McKeesport, Pa., Enamelled and Kalamine Pipe.

Neptune Meter Company, New York city, Meters.

Perrin, Seamans, & Co., Boston, Mass., Construction Tools and Water Works Supplies.

George Ross, Troy, New York, Regulator and Reducing Valves.

Rensselaer Manufacturing Company, Troy, N.Y., Valves.

Anthony P. Smith, Newark, N.J., Tapping Machine.

B. C. Smith, New York city, Pipe Cutting Machine, Meter Connection, Curb Stop and Eel Guard.

Taunton Locomotive Manufacturing Company, Taunton, Mass., Lead Furnace and Stop Box.

Thompson Meter Company, Brooklyn, N.Y., Meters.

Union Water Meter Company, Worcester, Mass., Meters.

Walworth Manufacturing Company, Boston, Mass., Valves and Tools.

R. D. Wood & Co., Philadelphia, Pa., Hydrants, Valves, and Cutting in Special.

The George Woodman Company, Boston, Mass., Stop Cocks and Knuckle Joint Shut-off.

A. R. Worthington, New York city, Meters.

Weir Meter Company, Salem, Mass., Meters.

ATTENDANCE AT THE CONVENTION.

ACTIVE MEMBERS.

Everett L. Abbott, New York city.
Charles A. Allen, Worcester, Mass.
Frank A. Andrews, Nashua, N.H.
R. C. Bacot, Jr., Hoboken, N.J.
Charles H. Baldwin, Boston, Mass.
Lewis M. Bancroft, Reading, Mass.
George E. Batchelder, Worcester, Mass.
Joseph E. Beals, Middleboro', Mass.
William R. Billings, Taunton, Mass.
Dexter Brackett, Boston, Mass.
John G. Brady, Worcester, Mass.
Arthur W. F. Brown, Fitchburg, Mass.
James Burnie, Biddeford, Me.
George F. Chace, Taunton, Mass.
E. J. Chadbourne, Neponset, Mass.
Charles E. Chandler, Norwich, Conn.
John C. Chase, Wilmington, N.C.
William F. Codd, Nantucket, Mass.
R. C. P. Coggeshall, New Bedford, Mass.
H. W. Conant, Gardner, Mass.
Byron I. Cook, Woonsocket, R.I.
George K. Crandall, New London, Conn.
George E. Crowell, Brattleboro', Vt.
Edwin Darling, Pawtucket, R.I.
Francis W. Dean, Boston, Mass.
J. H. Decker, New York city.
Nathaniel Dennett, Somerville, Mass.
Charles R. Dyer, Portland, Me.
Eben R. Dyer, Portland, Me.
Horace L. Eaton, Somerville, Mass.
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Ansel G. Hayes, Middleboro', Mass.
Clemens Herschel, New York city.
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David B. Kempton, New Bedford, Mass.
Joseph L. Kenney, Lewiston, Me.
E. W. Kent, Woonsocket, R.I.
Willard Kent, Woonsocket, R.I.
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Albert F. Noyes, West Newton, Mass.
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George E. Winslow, Waltham, Mass.
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James M. Betton, H. R. Worthington, New York city.
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Harold L. Bond, Perrin, Seamans, & Co., Boston, Mass.
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W. L. Beals, Civil Engineer, New Britain, Conn.
Mrs. Dexter Brackett, Boston, Mass.
Thos. Burke, Water Committee, Marlboro', Mass.
Patrick Byrne, Foreman, Marlboro', Mass.
Mrs. William F. Codd, Nantucket, Mass.
Mrs. R. C. P. Coggeshall, New Bedford, Mass.
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William D. Doyle, Marlboro', Mass.
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THE WORKS OF THE EAST JERSEY WATER COMPANY, FOR THE SUPPLY OF NEWARK, NEW JERSEY.

By

Clemens Herschel, Hydraulic Engineer, New York.

September 24, 1889, was signed a tripartite agreement between the Lehigh Valley Railroad Company, the East Jersey Water Company, and the City of Newark, New Jersey, of a somewhat novel form and tenor. Briefly stated, the Railroad Company, which by virtue of rights in the old Morris Canal controlled water rights that could be made useful towards the supply of water for domestic purposes to the city and elsewhere, became the sponsor and warrantor of the Water Company; the Water Company undertook to build works for the supply of Newark with pure and wholesome water, to the amount of 50 million gallons daily (77.35 cubic feet per second); the supply to the city up to, but not exceeding, 27½ million gallons daily, if so much be needed by the city, to commence May 1, 1892; the Water Company to have the right to draw from the conduit all that the city did not draw, until Sept. 24, 1900, and to control, maintain, and be responsible for the works to that time; the city agreeing to pay four (4) millions of dollars May 1, 1892, and two (2) millions of dollars additional on Sept. 24, 1900, when the complete 50 million gallons works were to be handed over to the city for its sole use and control. It will be noticed that the agreement partakes largely of the nature of a copartnership for 11 years. It enables the city to profit by the superior economy inherent in the purchase of rights and construction of works by a private company; while not exposing its citizens to such annoyance and oppression as may be incidental to a house-to-house collection of water rates by a private corporation. It is not intended here to discuss the mooted question of the relative merits of private or of public ownership for water works, only to point out the precise standing in this discussion, if it belong there, of the case in hand.

A parallel case is the contract by which the city of Philadelphia, owning and administering its gas works, yet contracts with a private gas company to deliver into its gas-holders gas by the million cubic feet. And apart from these two cases, the writer is not acquainted with similar contracts.

It will have been observed that only two working seasons, in all 2 years and 7 months, were allowed the Water Company in which to build the works. This short time will seem still shorter when it is considered that, beyond reconnoissances in the country whence the supply was to come, no surveys, still less designs of works to be built, had been made at date of signing the contract. The contract itself gives proof of the situation in this respect, in defining that the waters to be supplied are to be derived "from the Pequannock, Wynockie, or Ramapo water-sheds," being the Indian names of three tributaries of the Passaic river, in the State of New Jersey; of these three, the Pequannock (meaning, Black Water) became the decided favorite with the city authorities during the negotiations, and for this reason, among others, was the source finally selected by the Water Company. So that at time of signing the contract, this

much uncertainty had been practically eliminated from the undertaking, and there remained merely to build the required works from the Pequannock watershed to the city of Newark in 2 years and 7 months. As the new supply to the city of Newark has been in operation since April 26, 1892, it will be seen that this contract time was complied with; but it is necessary, for a proper understanding of the works about to be described, to remember that preliminary surveys, location, and construction proceeded simultaneously from the outset. Very great aid was derived in the early stages of the work from the excellent topographical or contour maps of the State of New Jersey; a piece of cartography no doubt destined to be of lasting renown to the State, and to its chief, the late Prof. George H. Cook.

At later stages of the work, the facilities for the making of large contracts afforded by the possession of ample monetary resources, and the influence and information possessed by the officers of the Lehigh Valley Railroad Company, became important factors in hastening the work.

While laying no claims to great elegance or monumentality of design, yet as a presentation of what modern facilities of construction can accomplish within a limited time, the works are believed to constitute an interesting exhibit. Some novel features of hydraulic construction embodied in them may also prove of interest to the ever-advancing profession of the civil and hydraulic engineer.

GENERAL DESCRIPTION.

The works consist in the main of two storage reservoirs: Oak Ridge, 383 acres of water surface, and Clinton, 423 acres of water surface, which discharge through the ancient and natural river and brook channels, 9 miles and 7 miles long, respectively, into the Macopin Intake Reservoir, 12 acres of water surface. Here commences the 48-inch steel conduit, 21 miles long, which carries the water to Belleville Reservoir, a low-service distribution reservoir of the city of Newark; thence branching from the main conduit is a steel pipe, 36 inches in diameter and 5 miles long, which leads to the South Orange-avenue Reservoir, a high-service city distribution reservoir.

In profile, we have Clinton wasteway on elevation 992 feet above mean level of the sea; Oak Ridge wasteway on elevation 836; Macopin Intake Dam on elevation 583.7; the hydraulic gradient of the conduit falling 2 feet per 1,000, and reaching Belleville Reservoir at elevation 358, while full water in Belleville Reservoir is on elevation 168.4; finally, the hydraulic gradient reaching South Orange-avenue Reservoir at elevation 300, in accordance with the terms of the contract, while full water in this reservoir is on elevation 226.6, though that of a new distributing reservoir, proposed to be built by the city, and to serve what is now called the "Special High Service," may be on elevation 300.

There is thus given 408 feet fall, on a distance of 7 miles of a mountain brook, for the water issuing from the Clinton Reservoir, and 252 feet fall, on a distance of 9 miles of a rocky river, for the water issuing from Oak Ridge Reservoir, in which to be aerated, in flowing down to the Intake. And the unusual amount of fall from the Intake to the points of delivery was utilized in generating velocity; that is, in reducing the diameter of the main conduit. As it has from the outset been intended by the East Jersey Water Company to supply out of the main

conduit and out of its water right of 22½ million gallons, or more, other cities and towns along the route, until Sept. 24, 1900 (thereafter from works to be built in the meantime), the waste of head or pressure at Belleville Reservoir is not without compensating advantages. The greater the head at Belleville, the wider the range of possible future water customers for the company. And after 1900, when the whole works will have passed to the city, the excess of pressure at Belleville may be utilized by the city, if desired, to produce a respectable amount of power; hence, in these days of power transmission, of income.

Oak Ridge Reservoir. — The reservoir at Oak Ridge has a drainage area appurtenant to it of 27.3 square miles; its water surface, as stated, is 383 acres; cubic contents, 2,555 million gallons; from high-water mark, on elevation 836, to the bottom of the outlet pipes is 44.5 feet. The dam forming it is an earth dam, of cross-section as shown on the drawings, being a straight dam, 40 odd feet high, slopes 2 to 1 on both sides, with a berme half-way up on each side, 16 and 10 feet wide respectively, on the water and on the down-stream side.

It has been argued that the same material that is required to make bermes on high earth-dams, if placed in form of a flatter slope on the dam, would be more effective to prevent slip, and for other purposes. The author is, however, ot the opinion that bermes are fully justified in the case of high dams, by the convenience they afford as level roadways from one side of the valley to the other, more especially during construction.

A core-wall of concrete extends from the ledge, some 28 feet below the original meadow surface, to the level of the full water-line of the reservoir. It is 8 feet thick at the level of the original meadow surface, and tapers to 5 feet thick at the top. It also tapers downward, following the lines of the sheet-piling, driven to support the sides of the trench. So far, the dam follows ordinary forms of construction. Its one peculiarity is a covering of small boulder-stone, some 3 feet thick, on the down-stream side, instead of the grass-surface usually cultivated on that side at a great expense of patient renewals after every rain. The reason for this was the excessive amount of stone found in getting the gravel with which to build the dam, which had to be culled out of the material to be dumped and rolled, but which had to be disposed of, nevertheless, somewhere. Their use, for the purpose named, has proved entirely satisfactory, and the author is prepared to recommend a repetition of this form of covering for the down-stream side of reservoir dams. It answers every constructive demand, and, as no one has ever, to the author's knowledge, said aught against the appearance of this slope-covering, while many have said that it gave the dams a look of great stability, it may fairly be claimed that æsthetic considerations, also, have been fully met by this covering of small boulders. On the water-side, a covering of the larger boulder-stone found in the gravel-pits was laid up as the dam was built, with gravel washed into the crevices.

The outlet channel of the reservoir is a cut blasted through the ledge around one end of the dam, this being done to avoid placing the gate-house in the body of the dam. In this channel is built a simple form of gate-house, consisting of two dry wells, in which to reach the four gates controlling the four outlet pipes. These latter are 42 inches in diameter, tapering to connect with 30-in. gates at

the centre, then gradually expanding again to 42 inches in diameter. A simple form of flap-gate can be lowered to close the up-stream end of each pipe, for the possible event of the 30-in. gate on that pipe needing repairs. By setting a 30-in. gate in line of a 42-in. pipe in the manner indicated, a material saving of expense is effected, without materially diminishing the capacity of discharge from what it would be with 42-in. gates, in line of the same size pipes. Experiments made on the discharge of one of these gate-house pipes will be given later.

The gate-house is roofed with iron beams and the ordinary cast-iron and glass city sidewalk covering, which lights and warms the interior of the dry wells in a very satisfactory manner. An iron railing completes the structure.

The wasteway is merely the top of a hill of ledge cut down to a uniform level, on a length of 350 feet, and discharging into the outlet channel.

The top of the dam is on elevation 842.5, or 6.5 feet above the crest of the wasteway, or 4 feet above extreme high-water mark, with 2.5 feet depth of water wasting; which would allow for 160 cubic feet per second per square mile, as the discharge during extreme floods.

Clinton Reservoir. — Clinton Reservoir has a drainage area appurtenant to it of 9.5 square miles; its water surface is 423 acres; cubic contents, 3,518 million gallons; from high-water mark, on elevation 992, to the bottom of the outlet pipe is 41.3 feet.

In cross-section, and generally, in method of construction, this dam and its gate-house are like the Oak Ridge Dam which has just been described. In ground plan, this dam is curved, being convex up stream, though it is needless to say in this place that this was done to take advantage of the natural topography for the purpose of reducing volume of dam, and not from any idea of securing strength with a minimum of volume, by virtue of such curved outline in plan. The gate-house also is somewhat different from the Oak Ridge Gate-house, in being in a rock-cut only at the bottom, this rock-cut arched over, and the dam built on either side of, and surrounding, the gate-house. A dependence on this rock-cut to hold water proved ill-founded, and the leakage through the rock-seams had to be stopped in 1892, by a layer of concrete on the floor of the ledge channel, and lining its sides with brick and cement masonry. The wasteway is partly in excavation, partly in low embankment, at one extreme end of the dam, and consists merely of the concrete core-wall, capped with stone, and having embankments on either side, of boulder stone, laid on a slope of 4:1, the interstices filled with gravel well washed in. Being so long, 300 feet for only 9.5 square miles of water-shed, the water can never run more than 1.5 feet deep, or at the rate of 180 cubic feet per second per square mile. For this reason, also, the top of Clinton Dam is only 5.5 feet above the crest of the wasteway, while it is 6.5 feet above the crest of the wasteway at Oak Ridge.

Macopin Intake. — The object of this dam is merely to form a small reservoir from which to take the water to be conveyed to the city into the conduit. This reservoir has a drainage area, especially appurtenant to it, of 25.9 square miles; making, with the Oak Ridge and the Clinton areas, 62.6 square miles appurtenant to the entire works; its water surface is 12 acres; cubic contents, 32 million gallons; from the crest of the dam, on elevation 583.7, to the bottom of the outlet pipes is 14.4 feet; but the hydraulic gradient of the conduit commences at elevation 579.2, or 4.5 feet below the crest of the dam.

The dam is a masonry structure, whose construction is sufficiently shown in the drawings. A novel feature is its location, being almost parallel with the original course of the Pequannock river. This line, and its curve, convex up-stream, was chosen on account of a ledge of rock of the described situation, on which to place the overflow dam or waste-weir; a wing approximately at right angles to the same, the top on elevation 590.7 so as to be beyond the fear of overflow, forming the rest of the water-retaining masonry. The wasteway is 250.4 feet long, so that allowing at the rate of 140 cubic feet per second per square mile, as the measure of extreme freshets, not over five feet in depth may be expected ever to flow over this weir; which will leave the water level two feet below the high part of the dam, and the foundation ledge gives ample security against possible undermining.

The gate-house is a simple structure, shown in the drawings, and serving to suitably connect the reservoir with the conduit. It is provided with three sets of screens; four regulating sluice-gates, to control the flow of water from the screening-chamber to the conduit chambers; and a cross-connection gate. by means of which the two separate conduit chambers may be connected. The southerly conduit chamber has no conduit leading from it at the present time, and is now used only as a sluice wasteway. Should a second conduit be built in the future, sluice wasteways may be formed by branches leading from the two conduits, close to the gate-house.

CONDUIT.

General Description. — No doubt the most novel part of the whole work is the 48-inch steel conduit; a riveted boiler shell 21 miles long.

Such riveted pipes have been common in California for the past thirty years, and have been made of all sizes from 10 inches up to 44 inches in diameter. They are described in De Bow's "Hydraulic Mining," and in papers by Hamilton Smith, Jr., M. Am. Soc. C.E., in the Transactions of the American Society of Civil Engineers, 1883 and 1884. Also in "Hydraulics," by Hamilton Smith, Jr., 1886, Trübner & Co., London.

The City of Rochester, New York, built a riveted conduit 36 inches and 24 inches in diameter, in 1874, but this conduit has cast-iron bell and spigot joints every 56 feet. This obviates the necessity of manholes, and avoids raising the question of expansion joints; so that the Rochester conduit is not a true riveted conduit of the California type. The conduit of the East Jersey Water Company is, on the other hand, distinctly of that type, and is, besides, larger in diameter than any hitherto built in California, or anywhere else, of any great length, so far as known to the author.

One of the most startling features about these conduits is the entire absence of any mechanical contrivances to take up expansion and contraction. The story goes that an engineer from the Atlantic coast, in reporting on what he had seen in California, described these riveted pipes, and added the criticism that those Californians didn't even know enough to provide expansion joints; "and, would you believe it," he added, "they found out that they didn't need any." Be the authenticity of this anecdote as it may, there was, prior to the construction of the works of the East Jersey Water Company, no precedent for such

omission of mechanical contrivances to take up expansion and contraction, outside of California, so far as the author knows. And those who have been placed in like positions will appreciate the weight of responsibility which had to be borne in deciding upon the course adopted, when the success of a $6,000,000 contract depended on such decision, and there was no time to make especial experiments. The author made a journey to California principally to study this question on the ground; various designs of expansion joints, and of bell and spigot, and other forms of semi-expansion joint, or of joints made otherwise than by riveting, were also studied; with the result that, to the author, the promise of success was distinctly greater from the use of riveted joints than from any of the other kinds of pipe joint. And it may as well be stated right here that three winters' experience has shown no defect that can be traced to a lack of any mechanical appliance to take up expansion and contraction. The first winter the pipe was empty, and thermometrical records show that the temperature went slightly below 32° F. on several occasions. The second winter much worse than this took place, and worse than is ever likely to happen again. The pipe line being completed December 31, the rest of the winter was spent in testing the pipe, and remedying defects thus discovered; an operation that involved a repeated filling and emptying of the pipe. This was done during the best available weather, but in spite of all care taken, the pipe must frequently have been filled with air of a temperature below 32° F., then filled again with water of 32° temperature; portions of it stood empty, or with still water in them, during severely cold weather; and so on. No effect has ever been observed as resulting from this treatment of the pipe line.

The phrase "mechanical appliance" has been used advisedly, for there is, of course, an adjustment of the forces produced in the body of the conduit by changes of temperature, though it is not brought about by any mechanical detail. This adjustment is self-acting, and is a compound of the friction of the pipe in the ground and of the elasticity of the metal forming the conduit. Computation will not reveal all the details of this action, but if, as may readily be done, the circular joints are made strong enough to safely resist the tensile strains that would be produced in the conduit supposing it anchored down at the two ends during a variation of 45° F. (32°—77°), no trouble need be apprehended from expansion and contraction, as has been demonstrated in actual practice. Needless to say, that this plan once adopted, it must be followed out consistently, along the whole length of the conduit. Thus all stop-gates set in line of the conduit must have flanges and bodies sufficiently strong to resist the tensile strain produced in the conduit under the assumed variation of temperature of 45° F. The proper rule to follow the author believes to be, to make such places excessively strong, so that the weakest points in the line shall be in the conduit itself, and not in any of its appurtenances; and an examination of some of the detail drawings will show this rule to have been followed; with the satisfactory results above noted.

Once rid of the expansion-joint bugbear, the comparison between riveted pipe and cast-iron pipe can readily be made in specific cases, as they arise.
present was a case in which a high velocity in the pipe was desirable, as a matter of economy; there was plenty of fall available, and a proper use of it would cause it to generate velocity; or, what is the same thing, diminish diameter.

The line followed gave 340 feet head on the pipe; and those two elements combined gave 6 feet velocity in a 4-foot pipe, under 340 feet head. These are measures which, if they do not positively exclude cast-iron, yet raise grave questions as to the practicability of cast-iron to meet them. Another objection to cast-iron was the length of time that would be required to cast 21 miles of 4-foot pipe, with all the foundries of large pipe in the country at work at it; or to lay it after it was furnished. And finally, an estimate of cost was largely in favor of the riveted pipe, even excluding the idea of a combination of pipe foundries to fix prices as they might want them.

Against the advantages of more trustworthiness, less cost, and less time required to construct, could only be put the fact that a steel pipe will float, and will collapse, under circumstances which do not similarly affect a cast-iron pipe; whence the necessity of guarding against such mishaps in the case of the riveted pipe by the proper designs and appliances. The question of durability was also raised, though the experience of the California lines of pipe for 20 years and over, that of the Rochester pipe for 18 years, and that of iron penstocks for water-power in the New England States for periods of 30 and of 40 years in single cases, is entirely satisfactory on the score of durability. The author has himself examined a length of some 200 feet of the Rochester pipe after it had been buried 18 years; also some photographs of the inside surface of two 20-inch discs cut from the same pipe, and is well acquainted with the appearance, inside and out, of New England penstocks of all ages, and can testify to the appearance, entirely free from rust, of the Rochester pipe, inside and out, and that the first case of a failure from rust of an iron penstock is yet to be heard from. It is true that the conduit of the East Jersey Water Company is of steel, while the principal experience had has been with wrought-iron. The preservative element is, however, the same in each case, being asphalt; and there is, over and above this, no reason to suppose that the superior metal will present any less resistance to corrosion than has wrought-iron. As will presently be seen in describing methods of manufacture, great care was taken to turn out a conduit which should be as securely protected from corrosion as could practically be accomplished.

While on the subject of choice of pipe, it should be stated that inquiries were extensively made as to the state of the art of tube-making, and whether any form of welded, or of seamless drawn, or of tube built up by processes other than by riveting, could be purchased, of desired quality, quantity, at an advantageous price, and within the desired time. While many such tubes were apparently on the point of being put on the market at advantageous rates, and some presumably will be at no distant day, no pipe was available in 1889 and 1890 which could compete with riveted steel pipe.

A novel feature of the pipe line is the fact that it has been designed and proportioned to resist, and is being operated to encounter, the pressures due to the hydraulic gradient only; in contra-distinction to those which would be produced by a hydrostatic head. This idea, while so far as known here first embodied in a finished pipe-line, had been previously suggested, as it now appears. Col. Geo. H. Mendell, Corps of Engineers, United States Army, proposed such a conduit for the city of San Francisco, in 1877; and Mr. Emil Kuichling, M. American Society Civil Engineers, now Chief Engineer of the Rochester

Water Works, who was Assistant Engineer in the construction of the Rochester Water Works in 1874, and again of the works of the East Jersey Water Company in 1889–90, independently hit upon the same idea. To carry it out in practice, it is only necessary to regulate the quantity flowing through the conduit by a sluice-gate placed at the up-stream end thereof, instead of by such a gate placed, as is usually done, at its down-stream end. In the case of open canals for irrigation, or for water-power purposes, this has been the method of regulation since such works were first constructed, and it may have been merely the author's many years' training on water-power canals that led him naturally to think of like methods for a closed conduit.

That such an arrangement is well worth striving for will appear from the fact that in case of the works of the East Jersey Water Company, this simple change effected a saving of fully 40 % in the weight, that is, in the cost of the manufactured conduit. At the present day, when a telephone has become one of the ordinary accompaniments of civilized life, there is no longer any excuse for building conduits any other way; so readily is the amount of water required in the distributing reservoirs controlled by the gate-keeper at the intake, in accordance with orders received by telephone. Finally, should the telephone line temporarily fail, the only harm that could occur would be a waste, at the distributing reservoirs, of the excess of water sent down; for which purpose waste-ways are provided; and to insure their being always open, no means are provided for closing them.

The telephone, be it said in passing, played as important a part in the construction of these works as it now does in their operation. The East Jersey Water Company built a telephone line of its own along the pipe-line, and to the several reservoirs. One instrument, called the "Perambulator," was moved along, from time to time, keeping pace with the progress of the work. Two portable instruments, with a pair of "climbers," formed, and still form, part of the outfit of the engineer corps, and can be put in circuit anywhere on the line in a minute or two. The author has frequently sat down on the ground in some field or piece of woods along the line, called up his office in New York, had the stenographer read him his morning's mail, dictated the replies thereto, called up other parts of the work, or called up two or three foremen on the line for a simultaneous consultation by wire; they and the engineer corps habitually did the same thing, so that it can readily be seen how the telephone contributed no little to the speed with which the whole work, stretched over 35 miles in length of territory, could be carried on. For the filling or emptying of the conduit, and generally for the conduct of hydraulic operations on the pipe-line, the telephone has shown itself — it is none too strong a term to use — invaluable. It may be credited with having caused a distinct advance in the possibilities of practical hydraulics.

We have then, as adopted, a riveted steel pipe, 4 feet in diameter, from Macopin Intake to the Belleville Reservoir, on a slope of 2 : 1,000, and a 36-inch pipe of this make, to branch from the 48-inch conduit near Belleville and extend to the South Orange-avenue Reservoir. There remains to speak of the appurtenances of the pipe-line, and of the process of manufacturing, and of laying the pipe.

PIPE-LINE APPURTENANCES.

Bridges. — In two cases is a river-crossing made on a bridge. The Pompton river and the canal immediately adjoining it are crossed by a four-span, ordinary wrought-iron truss-bridge, with the pipe hung on straps from the top chord. The Passaic river is crossed by a similar three-span bridge. All other brook and river crossings are either made by having the pipe support itself on spans not exceeding 10 feet, or by passing under.

Shut-off Gates and Interlocked Blow-off Valves. —There are on line of the 48-inch conduit nine 48-inch shut-off valves or gates, and two shut-off valves on line of the 36-inch pipe, besides the five 16-inch gates at the manifold to shut off the 36-inch pipe-line from the 48-inch conduit, at the junction of the two. These 48-inch valves are vertical valves with two 10-inch bye-passes, and are enclosed in little brick houses, forming at the same time tool-houses and depots of supplies along the line. The architecture of these gate-houses, and that of the very pleasing reservoir gate-houses mentioned later, is the work of Mr. Reuben Shirreffs, member of this Association.

The 36-inch valves are horizontal valves with 10-inch bye-passes, and are enclosed in underground vaults. In each case, excepting the two 48-inch valves furthest up-stream, the valve gear is so interlocked with the gear of an appurtenant blow-off valve that the shut-off valve cannot be closed until the blow-off valve has first been opened; and the blow-off valve cannot be shut again until the shut-off valve has again been opened. This is the arrangement adopted to prevent the possibility of an inadvertent closing of the shut-off gates while the water is running, or a turning on of the water while they are closed, the blow-offs being supposed shut in both cases; in either of which contingencies an excess of pressure would come upon the pipe up-stream from the shut-off gate in question. As regards the first gate above noted as an exception to the rule, it is located at a point such that the conduit up-stream from it can withstand the static head; and as regards the next gate down-stream from this, being the one at the foot of Pompton Notch, it is not interlocked with a blow-off, because there is an open overflow pipe on the hydraulic gradient in the Pompton Notch which would relieve the conduit from any excess of pressure caused by any possible handling of the gate at the foot of Pompton Notch. A study and test of relief valves such as ordinarily made and in the market, also of designs for such appliances by competent engineers, was conclusive in showing their excessive cost and the risk of depending on such for the discharge of a possible seventy-seven cubic feet per second. Such relief valves are mostly held down by springs, and the water pressure to open them is an entirely different and a greater one, so long as they are yet shut, than the pressure which obtains to keep them open after they have once begun to discharge water; and to make the matter worse, the action of the spring tending to hold them shut becomes stronger as they are lifted, so that none of them open very far or discharge any proper quantity of water at times when a copious discharge is needed, or is theoretically to be expected. Dead weights on the valves have the same and still other objections. Besides this, it must be remembered that relief valves in such a position would be expected to stand ready to operate for twenty years or more without deterioration, and yet be expected to fail not properly to act at the precise moment.

From all of which considerations it is submitted that the interlocking blow-offs adopted were the preferable apparatus.

It is proper to state in this connection that these 48-in., 36-in., and interlocking blow-off valves, and gear thereto appurtenant, were furnished by the Eddy Valve Company, of Waterford, N.Y., and that they have given entire satisfaction to date.

Pressure Regulators. — At the two terminal chambers, or reservoir gate-houses, however, it was necessary to set relief valves or pressure regulators, although these pressure regulators at the reservoirs will become superfluous when the city of Newark will have completed its new special high-service distributing reservoir. This simple but excellent apparatus was made by the Ross Valve Company, of Troy, N.Y., and is shown in the drawings. The operating part is the small relief valve I, set at the required pressure by the hand-wheel H. When this valve opens, an excess of pressure is formed in the chamber K, which depresses the main valve M, thus relieving the pressure that caused I to open. As a matter of safety, the piping and relief valve I is made in duplicate. As there are three pressure regulators in the Belleville Gate-house, each of which is governed by two independent relief-valves, there is a large measure of certainty of operation always at hand. Besides having the regulators set either in a locked-up gate-house, or else placed in charge of a keeper, the hand-wheels are taken off of all the valves, and the appurtenant shut-off valves are all made with indicators, to show whether they are open or shut; these and a proper supply of recording and alarm and ordinary pressure-gauges being precautions against an improper or unauthorized handling of the apparatus.

The positively best arrangement would be to have a separate conduit for the high and for the low service; to have no means of shutting off the water, whether automatically, as in pressure regulators, or by shut-off gates within the terminal gate-houses; that is, to have the down-stream end of the conduits always, and of necessity, wide open; and to have a reservoir at the desired elevation, for the delivery of the water. This last condition is likely soon to be realized, upon which the other two are not unlikely to follow in course of time.

Air-valves. —The office of automatic air-valves on a steel or wrought-iron pipe-line is to let the air out of the pipe when it is being filled with water; to let the air into it again when the pipe is drawn; also, to let air into the pipe, and thus prevent the collapse of a long stretch of pipe, should, by any accident, such as a breakage of a blow-off connection, or of the pipe itself, a large quantity of water suddenly flow out of the pipe. To this has been added in the same casting an ordinary valve, by means of which accumulated air may be let out of the pipe while it is in operation. The basis of the automatic air-valves is a brass cup, $3\frac{1}{16}$ inches in outside diameter, and 4 inches high, turned bottom up, and light enough to float on water. The upturned bottom forms the valve disc, which is made to set up against the valve-seat, when the cup, floating up between brass guides, and after the air contained in the pipe has been blown out, is reached by the rising water. The air imprisoned within the cup forms an air-cushion for this upward thrust. When the water leaves the cup, it at once falls down between the guides already mentioned, and thus leaves the whole area of the air-valve open for the entrance of air. These cups are mounted in

clusters of four, six, and ten, being the equivalents of 6-in., 8-in., and 10-in. connections, and each cluster is fitted with a valve to be operated by hand, as already mentioned. Under each cluster is a shut-off valve, to be used in case of any defect in the air-valves requiring repairs. The air-valves used were made by the Coffin Valve Company, of Boston, Massachusetts, who also made the Intake Gate-house sluice-gates, and gate-house ironwork generally; all of it, in the most satisfactory manner.

These air-valves were proportioned such that in the event of the pipe being cut in two at the most dangerous point, the water rushing out and air rushing in would, between them, at no time cause more than ½ atmosphere of vacuum inside the pipe.

As the pipe was barely finished in 1891, there was no time to build underground vaults to keep these air-valves from freezing. Instead of these, there was designed a most wonderful structure, as such things go, called an air-valve box. It must let air in freely, and let air out freely, according as the pipe is drawn or is filled, but it must not allow the valve to freeze up. It must afford access to the hand-valve and to the air-valve, and must let air or water out when the hand-valve is opened, but again must not let any of the valves freeze up. It must let out the water that spills at the moment when the air-valves are shut by the rising water, or the possible larger quantities, should, from some obstruction or defect, one of the air-valves fail to close tight; but, again, must not let things freeze up by the route taken for the water to get out. The great American boy must be prevented from dropping stones or sticks into the boxes, and the shut-off valve must be so fitted that it can at any time be operated. The drawings will show how these several requirements have been met. A cellar pit is first built around the air-valves, and this is floored over with loose boards, or with panels of such. On this is laid a cheap form of quilt, made in two halves. The ordinary straw or other winter stuffing will not apply in this case, for fear of pieces of straw or other stuffing getting into the valves. Over this is the box proper, pierced by two or four wooden square chimneys, hooded to keep out the rocks and sticks. In these chimneys swings a flat plate of sheet-iron, which shuts off the chimney when this plate is in a horizontal position. It is normally held horizontally, by a lead ball attached vertically beneath the centre of the plate by a short wire rod, but will swing out of its horizontal position to pass a current of air going either up or down the chimney, and will duly return to the normal position when the air-current ceases. Flap-valves in the several outlet pipes perform the same office of keeping out the cold, as far as they are concerned. The rest of the design of these air-valve boxes is made clear by the drawing. The author presents the finished and tried air-valve box to the profession, without showing the successive steps by which it was developed from the trial air-valve box first designed. That no valve froze up during the very trying first two winters of the operation of the pipe is praise enough for the box as shown.

Blow-offs and Manholes. — It goes without saying that blow-offs had to be provided at all depressions, so that the pipe could be emptied; and manholes placed at proper distances, so that the interior of the pipe could be visited during and after construction. On the 48-in. pipe there are manholes every 1,000 feet; on the 36-in. pipe, every 500 feet.

Manifold Connections.— To connect or branch off a 36-in. from the 48-in. pipe, as was done at Pompton Notch and at Belleville, the neatest way seemed to be to do this by a series of 16-in. thimbles riveted to the 48-in. pipe, which were then gathered together again into the desired 36-in. pipe. All of which is shown on the drawings.

Venturi Water-meters.— As the main 4-ft. conduit is to supply several municipalities, a metering of the water carried by it and by its branches had to be provided for. For this purpose there exists, so far as the author knows, but one practical meter at the present day, described by him in the Transactions of the American Society of Civil Engineers, November, 1887, and June, 1888, which articles describe also the carefully conducted tests of a 108-in. meter, discharging nearly 250 cubic feet per second, and of a 12-in. meter.[1]

There are on the line of the East Jersey Water Company, up to date, four such meters, two 48-in., one 36-in., and one 16-in. meter, which are shown on the drawings. It may be proper briefly here to repeat a description of the method of operation of these meters, which is extremely simple. It is based on the properties of the Venturi ajutage, in causing, within limits, the small section of a gently expanding frustrum of a cone to discharge as much water as the large end, without material resultant loss of head; and on that further property, which causes the pressure of the water flowing past the small section to be less, by virtue of its greater velocity, than the pressure thus exerted at the large end; each pressure being at the same time a function of the velocity at that point and of the hydrostatic pressure which would obtain were the water still within the pipe. The apparatus accordingly takes the shape of two frustrums of a cone set in line of the pipe whose discharge is to be metered, with their two small ends joined by a short throat-piece. The water pressure is measured just up-stream from the large end of the first cone, and again at the throat. The difference of pressure at these two points forms a most exact measure of the mean velocity through the throat, and the total loss of head caused by the whole apparatus can be kept within desired limits by a proper proportion between the area of the main pipe and of the throat. Ordinarily this proportion is between $\frac{1}{9}$ and $\frac{2}{9}$, and so long as the velocity through the throat of the meter is less than about 24 and 34 feet per second, the total loss of head caused by the meter will be less than one foot and two feet respectively. The 48-in. Venturi meters above mentioned will pass 25,000,000 gallons per day, with a loss of head due to passing the meter of only four inches of water column.

Algebraically stated, the theory of the meter is as follows :

Let P be the pressure, in terms of the height of a column of water, at the up-stream end of the meter.

Let P_1 be the pressure, similarly expressed, at the throat.

Let v and v_1 be the velocities of the water, at the same two points, respectively.

Let Ps be the static pressure; then

$$P = Ps - \frac{v^2}{2g}$$

$$P_1 = Ps - \frac{{v_1}^2}{2g}$$

[1] See also Vol. vii. p. 32, this Journal.

Also: $v_1 = 9v$, from the construction of the meter, in the case that the diameter at the throat is ⅓ the diameter of the main pipe. Subtracting the equations we have

$$P - P_1 = \frac{80}{81} \frac{v_1^2}{2g.}$$

But $P - P_1$ is the difference of pressure at the two piezometers, and is the head on the "Venturi," or on the throat. Calling this H_v, we have v, the velocity through the throat,

$$= \sqrt{\frac{81}{80}} \sqrt{2\ gH_v} = 1.0062 \sqrt{2\ gH_v};$$

whereas experiment on meters of 12, 48, and 108 inches diameter gives for extreme values in the three meters, within their range of capacity to meter, $v = 1.02$ to $0.90 \sqrt{2\ gH_v}$; varying with the velocity through the throat, and more especially when approaching the lower limit of velocity. For more than ⅞ of the extreme range of capacity to meter, this range of coefficient for the *three meters* is only between 1.00 and 0.94. These figures show what may be expected from any meter, set to work without first testing it; but any one meter after having been rated, will record within a small fraction of one per cent. of the exact quantity passing the meter.

Before the piece of main conduit pipe which immediately adjoins the Intake Gate-house was set in place, an open wooden flume was built to convey the water from the gate-house to the pipe already laid. A carefully constructed weir was set in this flume, and a series of experiments were made to determine the discharge of the Venturi meter set in the conduit; also of the gate-house sluice-gates, under varying conditions of quantity and of head. These two sets of rating were carried on simultaneously, as the same stream of water passed first the sluice gates, then the weir, then the Venturi meter. And the results of these ratings will be given later. It will be noticed that the rating of the 48-in. Venturi meter made in 1891 agrees perfectly with the ratings of the 108-in., and of the 12-in. meter made in 1887.

So far, the Venturi meter has been described as forming an apparatus by means of which only the rate of flow in a pipe can be measured at any desired moment of time. But the Builders' Iron Foundry, of Providence, Rhode Island, which builds these meters, has added a recording gauge or recorder, which causes the Venturi meter to register quantities (cubic feet or million gallons) in precisely the same manner that ordinary meters register quantities.

This recording and integrating gauge has never yet been publicly described, but is on exhibition at the World's Columbian Exposition. There may be an electrical connection between the dials and the mercury gauge, thus permitting the former to be set up at any distance from the latter, which at times becomes very convenient. Besides this, the recorder itself can be set up hundreds of feet, if need be, from the Venturi meter, for it is operated by two pipes conveying water *pressure* only (not a current of water), and such pipes need have but a small diameter, and can convey such pressure through any reasonable length of pipe.

Making of the Conduit. — The conduit is made of open hearth steel, bought to conform to the following specifications, as to quality:

"Tensile specimen to be eight (8) inches long and one and one-half (1½) inches wide between measuring points. Tensile strength to be between the limits of 55,000 and 67,000 pounds per square inch. Elastic limit to be not less than 30,000 pounds per square inch. For plates ⅜ inch thick and heavier, elongation to be not less than 25 % longitudinally on the plate, 22 % transversely on the plate. Plates thinner than ⅜ inches, elongation to be not less than 22½ % longitndinally, and 20 % transversely on the plate.

"Bending specimen to be six inches long and one inch wide, and to be hammered down flat, when cold, without showing cracks.

"Test to be made from 20 % of the plates selected at random.

"Steel to contain not more than six one-hundredths per cent. phosphorus, and six one-hundredths per cent. sulphur, and sixty one-hundredths per cent. manganese."

This high quality of metal was chosen so as to leave no doubt as to the expediency of punching the plates, instead of drilling, or of punching and reaming them. This selection of steel cost the Water Company $85,000, as Bessemer plates could have been bought for that much less; but no $85,000 spent on the works was probably better invested. Apart from the advantage of being able to punch the plates without injury to them, there has seemed to be no expected or unexpected strain to which the pipe has been subjected, that it has not been able, largely by virtue of the superior metal of which it was constructed, to withstand without injury.

This steel was from the works of Carnegie, Phipps & Co., and was shipped in plates from Homestead, Pa., to the pipe works at Paterson, in cars especially built for the purpose, by the Lehigh Valley Railroad Company, as fully described below.

Shop riveting was done by machines, and using open hearth steel rivets, of a tensile strength between 57,000 and 63,000 pounds per square inch, and of an elastic limit of 30,000 pounds.

Field riveting was done by hand, and using iron rivets of a tensile strength of 55,000 pounds, and an elastic limit of not less than 27,500 pounds.

Each length of pipe as shipped on railroad cars was made up of four plates, each plate seven feet wide, and long enough to make one section of the pipe; making about twenty-seven feet of pipe, made up of two long sheets and two short ones. Various data with regard to such a length of pipe are given in the accompanying table.

General Dimensions.	Inches.	Inches.	Inches.	Inches.
Nominal size pipe............	48	48	48	36
Thickness sheets.	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{4}$
Size large sheets............	$154\frac{3}{4} \times 84$	$155\frac{3}{8} \times 84$	$156\frac{1}{16} \times 84$	$118\frac{3}{4} \times 84$
Size small sheets.............	$153\frac{1}{8} \times 84$	$153\frac{1}{4} \times 84$	$153\frac{5}{8} \times 84$	$116\frac{7}{8} \times 84$
Inside diameter of large ring..	48	48	48	$36\frac{1}{2}$
Inside diameter of small ring..	$47\frac{1}{2}$	$47\frac{3}{8}$	$47\frac{1}{4}$	36
Size of rivets................	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{5}{8}$
Size of rivet-hole	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{15}{16}$	$\frac{11}{16}$

Circular Seams.	Inches.	Inches.	Inches.	Inches.
Number of rivets per seam ...	100	84	76	76
Circumference of large sheets,	151.582	151.779	151.975	115.641
Circumference of small sheets,	149.895	149.717	149.538	113.883
Rivet pitch, large ring	1.515	1.807	2.053	1.521
Rivet pitch, small ring	1.498	1.782	2.020	1.498
Distance from centre rivet to edge plate.................	1	$1\frac{3}{16}$	$1\frac{3}{8}$	1
Lap of sheets at circular seam..	2	$2\frac{3}{8}$	$2\frac{3}{4}$	2

Longitudinal Seams.	Inches.	Inches.	Inches.	Inches.
Number of rivets in first row..	35	29	25	35
Number of rivets in second row,	34	28	24	34
Rivet pitch, both rows	2.277	2.721	3.125	2.277
Distance between rows	$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{5}{16}$	$1\frac{1}{16}$
Diagonal pitch..............	1.557	1.806	2.041	1.557
Distance pitch line to edge plate,	$\frac{15}{16}$	$1\frac{5}{32}$	$1\frac{11}{32}$	$\frac{15}{16}$
Lap of sheets...............	3	$3\frac{1}{2}$	4	3

The California practice is to carry a portable punch, shears, and bending-rolls into the field, and make all bends needed to fit the ground, on the spot. On the work of the East Jersey Water Company the engineer corps devised the plan of forming all bends by means of only four standard bevels, used in combination with the standard 28-ft. length of chord, or of straight pieces of pipe. This made curves of 2½, 5, 7½, and 10 degrees of curvature, and no other curves were used on the survey of the pipe line. Vertical curves, also, were made on 10 degrees of curvature. So that the whole pipe was laid out in the shop, to fit the ground as it had been surveyed; each piece was tagged with a tin tag and number, signifying where it belonged on the line, and was laid in the ditch at the points corresponding to its tin tag without further fitting or trimming.

The author being strongly of the opinion that to insure the preservation of any metal from rust it is necessary to coat the same before any rust has begun to form, great pains were taken to get the plates from the rolling-mill to the pipe-shop in a clean and bright condition. Several plans for this were tried without success. One of them consisted in dipping the plates in paraffine at the rolling-mill, and failed on account of the resultant difficulty in passing such coated plates through the bending-rolls. The system finally adopted was to have 40 special cars for this "trade" alone, and to keep constantly passing the loaded cars to the shop, and the "empties" back to the rolling-mill. These were new coal-cars, with deep bodies, and with a specially constructed, removable flat roof, as a cover for the plates; made in two sections, and flat enough for brakemen to walk on. These roofs could be lifted off and put on by the same cranes that handled the plates. Both loading and unloading being done under cover, the plates, when everything was going well, were shipped, received, made into pipe, and dipped, before rust had a chance to show itself.

The dipping was done in iron vats built especially for the purpose, one length of pipe at a time. The material used to dip into was asphalt, from Southern California. Asphalt is found in Southern California in two forms: (1) combined with 40 to 60 % of sand, making rock asphalt; and (2) in liquid form, being combined with a species of petroleum. To use the first, it must be refined; that is, melted out of its combined sand, then remelted, and mixed with a certain proportion, usually, of coal tar, to give it a proper consistency for having pipe dipped into it. The liquid asphalt, on the other hand, must be distilled until the bitumen remains as a residuum; and this, when remelted, is usually mixed to make it more fluid, or viscous, with the product of the same wells, taken at a lesser stage of distillation. The distilled asphalt used on these works was shown by repeated chemical analysis to be 98 % pure bitumen.

The sheets, as received, were punched by gang punches, bevel-planed on the edges, rolled into cylinders, riveted by hydraulic riveters, calked with the pneumatic calker (by hand only in odd places), and twice dipped, as stated, in boiling asphalt.

Four lengths of pipe, two lengths below, two on top, made a neat car-load, and one length at a time was a two-horse wagon-load on good roads, or a four-horse load up the mountains; which brings the pipe to the side of the ditch.

Laying the Pipe. — Pipe-laying commenced Sept. 20, 1890, at the crossing under the Pequannock river. The contract for making and dipping the pipe, delivering it side of the ditch, and riveting it together in the ditch had been let,

January 18, to Messrs. McKee & Wilson, boiler-makers, then of South Bethlehem, Pa. The interval had been spent in getting a shop built, at Paterson, N.J., riveters and other tools made and set up, and generally in getting the pipe works started. In the following April, a contract was made by the Water Company with Messrs. T. A. & R. G. Gillespie, of Pittsburg, Pa., for digging the ditch and back-filling; the contractors for making the pipe contracting at the same time, with the same parties, for riveting the pipe together in the ditch. This was a much better arrangement, making, as it did, two consecutive pieces of work of the building of the conduit: (1) the making and delivering of the pipe, and (2) laying the conduit, that is, digging the ditch, riveting the pipe together in it, and back-filling over the pipe; instead of, as before, having the Water Company dig the ditch and back-fill it, with the riveting together of the pipe by another party, in between these two operations.

About 1½ miles of pipe were laid in 1890, this work coming to a stop with the hard frosts of December.

The settled method of laying pipe soon came to be to rivet two lengths together, side of the ditch, making a 54-feet length; to lower these 54-feet lengths into the ditch, and connect them by bolts, temporarily. Then rivet up; each circular joint being made, the lower half from the inside, the upper half from the outside. Cover the pipe as soon as possible with earth, as a guard against undue expansion and contraction, taking care to tamp well up to a point either side of the pipe, which is somewhat above the horizontal diameter of the pipe. If need be, cover in this way before all the field joints are riveted, and leave uncovered only the joints yet to be riveted. Protect both inside and outside the pipe with old canvas, carpets, etc., in a careful manner, against abrasion of the asphalt, by the workmen walking on and in the pipe. Have riveters and others wear rubber boots. See that all abrasions of asphalt, caused in transport, are retouched before the pipe is lowered into the ditch.

For retouching pipe in this way, extensive use was made of "P. & B." paint, which is merely asphalt dissolved in bisulphide of carbon, the bisulphide taking the place of the linseed oil of ordinary paint. After this paint is applied, the bisulphide evaporates, and there is left a coating of practically pure bitumen. This paint did most excellent service throughout the work. In June, 22,165 feet of pipe were laid in the ditch, making the maximum month of pipe-laying; though in May, June, and July the average was 19,347 feet.

Pipe-making never exceeded these rates of pipe-laying, when work went on night and day, and usually was much less, because not so hurried. There was no such need of hurrying it, from the fact that pipe-making could be carried on every day and all winter, while pipe-laying had to stop in the winter and in rainy weather. The work of the pipe-shop represents that of three hydraulic riveters, and of enough other machinery to keep them going.

The water was first turned on at 8 A.M., Dec. 30, 1891, while the last manhole plate was screwed down at about 10 A.M., the same day, but at a point some 8 miles from the Intake gate-house.

Before turning on the water, the corps of inspectors of the pipe-work in the field was directed to walk through the pipe, from end to end, in consecutive days' journeys. The 4-foot pipe can be readily walked through, with a little stooping, but to walk through the 36-inch pipe, the inspector must go on his hands and knees, at the same time carrying a lantern in his mouth, or set in his

hat. To illustrate the utility of such an inspection of hydraulic works, a list of the articles found in these 26 miles of pipe, all built under inspection, and supposed to contain nothing when the final inspection commenced, is here given:

1 cedar post.
2 brooms.
1 paint pot, and brush in it.
1 holding-on sledge.
1 dolley-bar and strap.
1 3-ft. piece of board.
1 2-ft. piece of plank.
1 18-in. piece of plank.
1 bottle.
3 washers.
1 round piece of steel.
1 rivet.
½ pail of iron scraps.
1 half-pint of steel clippings.
3 wooden wedges.
1 10-ft. piece of canvas.
3 6-ft. pieces of canvas.
2 3-ft. pieces of canvas.
2 small pieces of canvas.
1 pair of pants.
1 pair of suspenders.
1 pair of overalls.
½ dozen good-sized stones.
1 stone, size of your fist.
1 hat full of small stones.
½ dozen small stones.
1 pint of pebbles.
2 pieces of a glove.
1 half-bushel of clay.
1 bunch dried leaves.

Besides this, the inspectors found a rivet-hole without a rivet in it, in a shop seam. Two more such rivet-holes in field seams, and three 1½-inch plug holes (used to drop the red-hot rivets into the pipe), similarly devoid of metal to stop them up, the inspectors did not find from the inside; though there was no difficulty in finding them from the outside after the water had been turned on.

The water first reached Belleville Reservoir January 12, having been allowed to fill the pipe by day only, and proceeding cautiously along the whole length. Also, drawing off and remedying defects as they were developed. February 15, the water first reached the South Orange-avenue Reservoir, having been delayed to await the completion of the high-service gate-house. The city of Newark has pumped no water for the consumption of either the low or the high service districts since April 26.

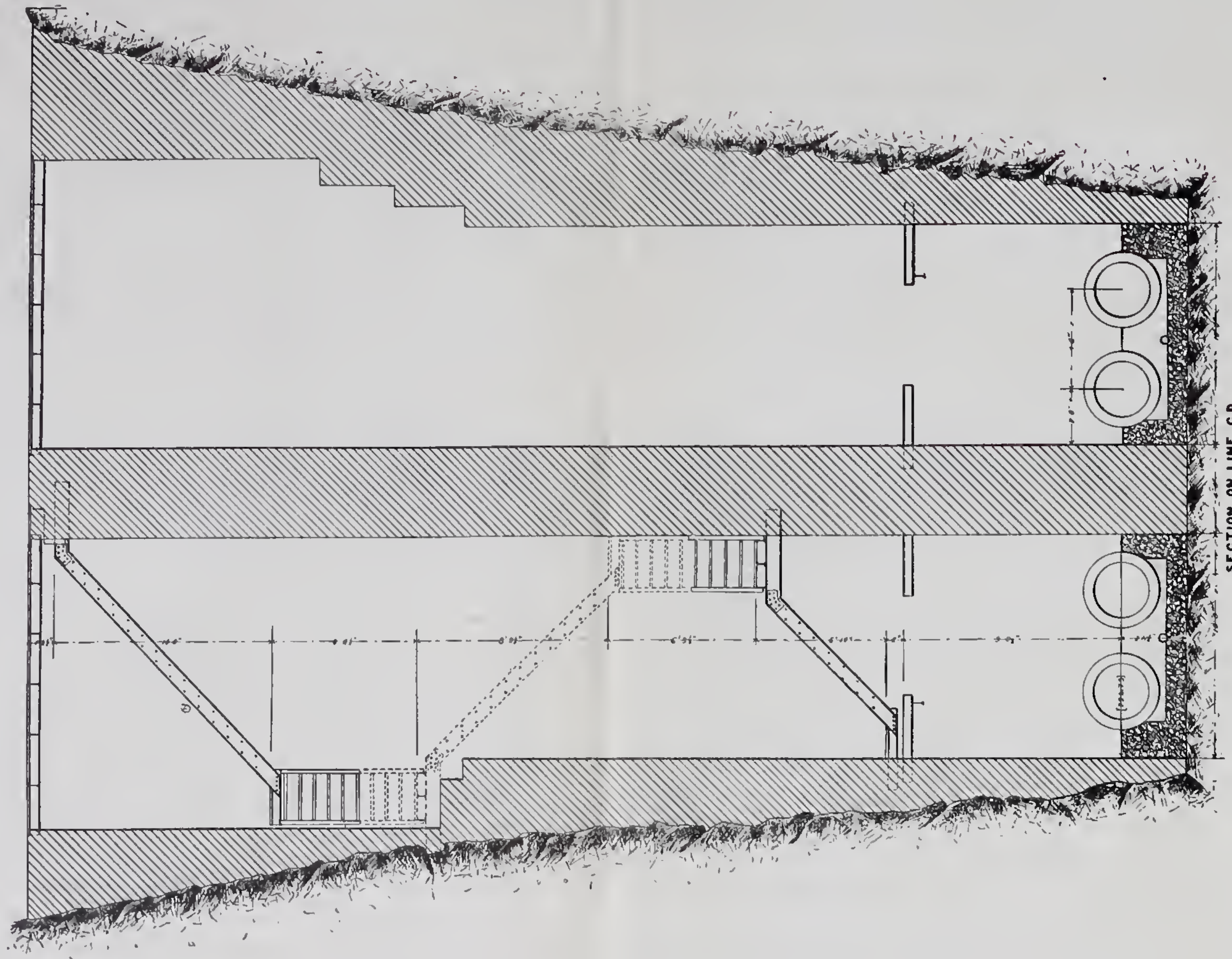
Hydraulic Experiments. — Among the illustrations will be found diagrams giving the results of such hydraulic experiments as have been made on the works to date. Others yet to be made may form the subject of a future communication.

Those now given comprise (1) the discharge of one of the head-gates, or sluices, at the Macopin Intake; (2) the discharge, and the loss of head occasioned by the 48-inch Venturi meter set in line of the pipe near Macopin Intake; (3) the discharge of one of the outlet gates of the Clinton reservoir.

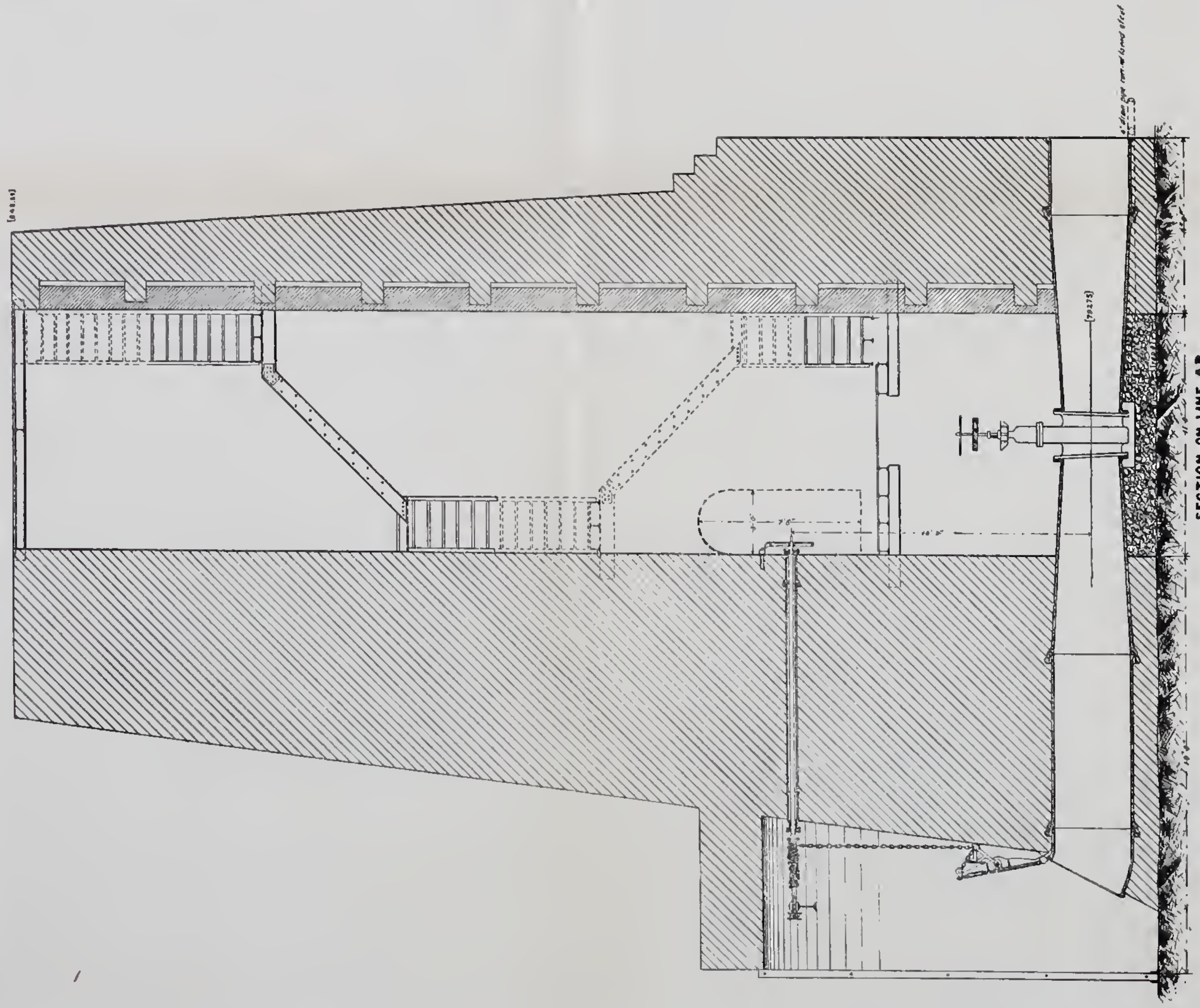
The following table illustrates the action of the three principal parts, and of the whole, of the drainage area and of the reservoirs in supplying 50 million gallons daily. It is based on careful daily measurements of the natural flow of the river, being the flow of the river as it would have been at the Intake Dam, had there been no works constructed by the East Jersey Water Company, and on an assumed draft of 50 million gallons daily during the same time. It is the intention to continue these daily gaugings and records, as part of the duties of operating the works. If continued long enough, these tables will evidently present just as good a measure of the capabilities of the drainage area in question as any tables of rainfall, with their annually and monthly varying appurtenant coefficients of yield, can possibly present.

Flow of the Pequannock River by weeks, and Volume in Store in each Reservoir, if Fifty Million Gallons per day had been drawn through the Conduit, beginning June 1, 1891.

	All Quantities in Million Gallons.											
	Flow of River per Drainage Area.			Total Natural Flow of River.	Taken from or added to Oak Ridge.	Volume in Oak Ridge.	Taken from or added to Clinton.	Volume in Clinton.	Waste from each Drainage Area.			
	Macopin.	Oak Ridge.	Clinton.						Macopin.	Oak Ridge.	Clinton.	Total Waste.
1891.						2,558						
June 1 to 7 . .	91	94	33	218	— 132	2,426	. . . .	3,539				
8 to 14 . .	73	75	26	174	— 176	2,250	. . . .	"				
15 to 21 . .	39	40	14	93	— 257	1,993	. . . .	"				
22 to 28 . .	44	45	15	104	— 246	1,747	. . . .	"				
29 to July 5	31	30	11	72	— 278	1,469	. . . .	"				
July 6 to 12 . .	25	25	9	59	— 291	1,178	. . . .	"				
13 to 19 . .	21	21	7	49	— 301	877	. . . .	"				
20 to 26 . .	31	31	11	73	— 277	600	. . . .	"				
27 to Aug. 2	38	39	14	91	— 259	341	. . . .	"				
Aug. 3 to 9 . .	32	33	11	76	— 274	67	. . . .	"				
10 to 16 . .	30	30	11	71	. . . .	"	— 279	3,260				
17 to 23 . .	68	70	24	162	. . . .	"	— 188	3,072				
24 to 30 . .	481	492	172	1,145	+ 492	559	+ 172	3,244	131	. .	. .	131
31 to Sept. 6	170	173	60	403	+ 173	732	— 120	3,124				
Sept. 7 to 13 . .	135	139	48	322	. . . .	"	— 28	3,096				
14 to 20 . .	61	62	22	145	. . . .	"	— 205	2,891				
21 to 27 . .	48	49	17	114	. . . .	"	— 236	2,655				
28 to Oct. 4	42	42	15	99	. . . .	"	— 251	2,404				
Oct. 5 to 11 . .	43	44	16	103	. . . .	"	— 247	2,157				
12 to 18 . .	31	31	11	73	. . . .	"	— 277	1,880				
19 to 25 . .	40	40	14	94	. . . .	"	— 256	1,624				
26 to Nov. 1	28	28	10	66	. . . .	"	— 284	1,340				
Nov. 2 to 8 . .	31	31	11	73	. . . .	"	— 277	1,063				
9 to 15 . .	72	73	26	171	. . . .	"	— 179	884				
16 to 22 . .	325	332	116	773	+ 307	1,039	+ 116	1,000				
23 to 29 . .	288	365	118	771	+ 303	1,342	+ 118	1 118				



SECTION ON LINE C D



SECTION ON LINE A B

THE

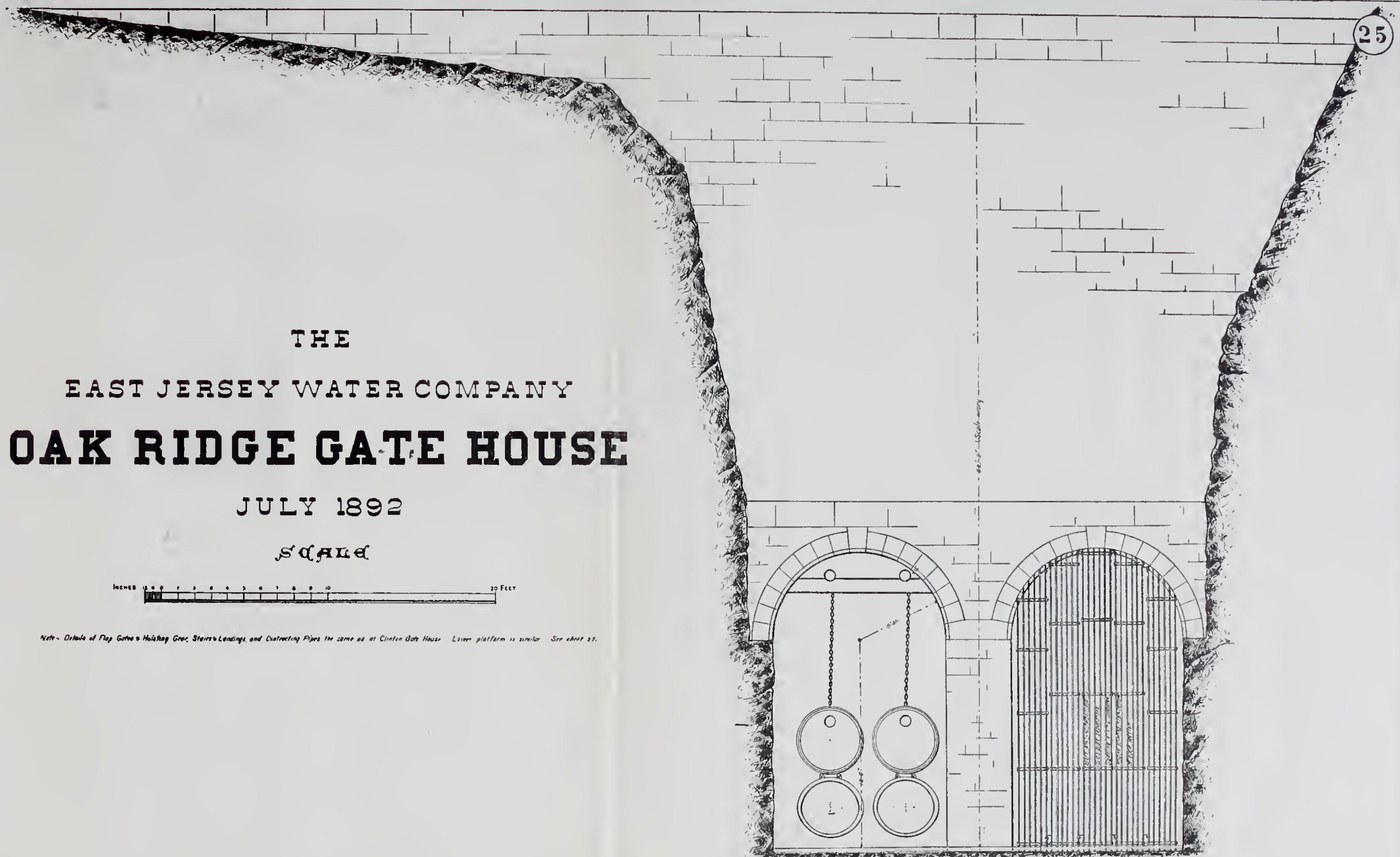
EAST JERSEY WATER COMPANY

OAK RIDGE GATE HOUSE

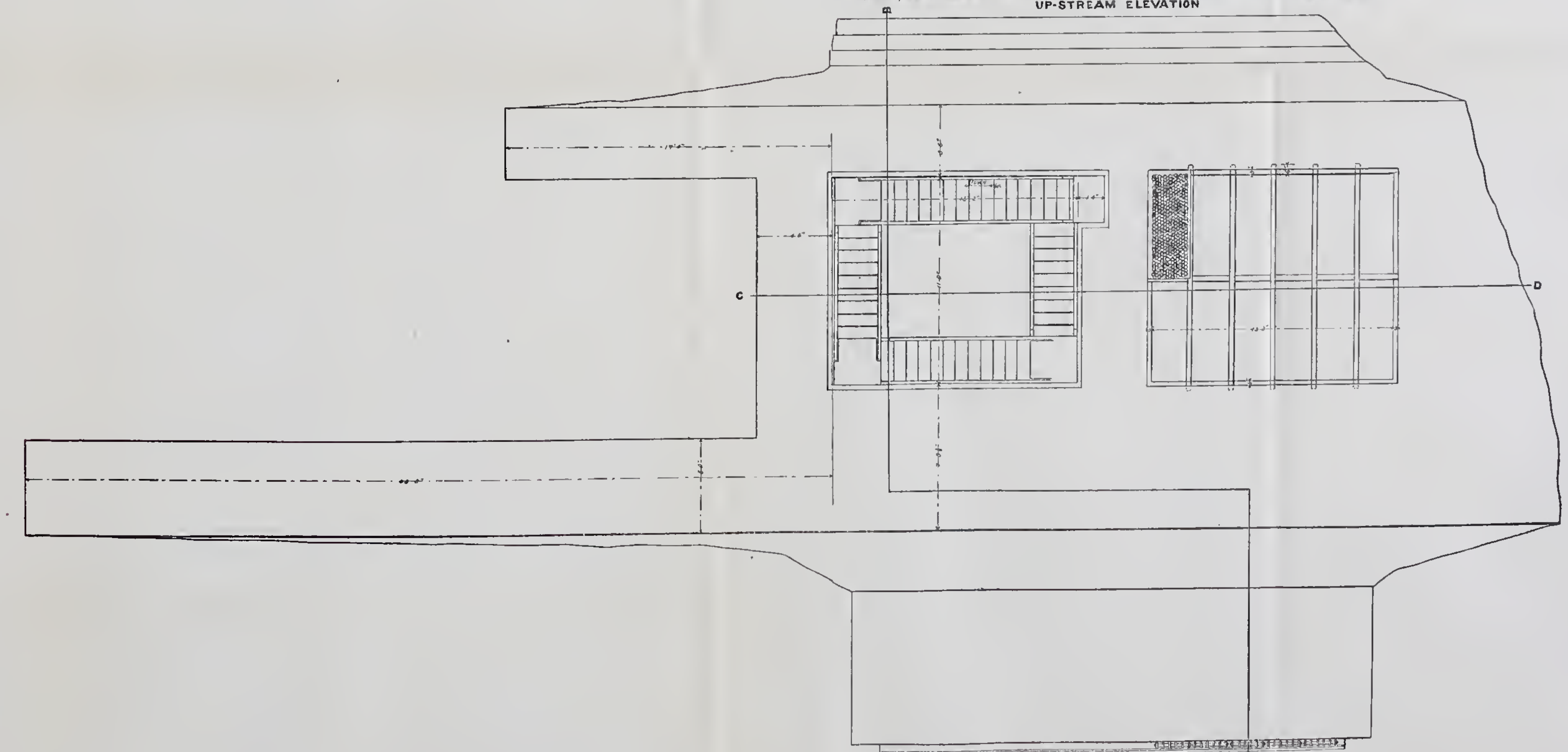
JULY 1892

SCALE

Note – Details of Flap Gates & Hoisting Gear, Stairs & Landings, and Contracting Pipes the same as at Clinton Gate House. Lower platform is similar. See sheet 27.



UP-STREAM ELEVATION



PLAN

3

Ju

Jul

Au

Sep

Oct.

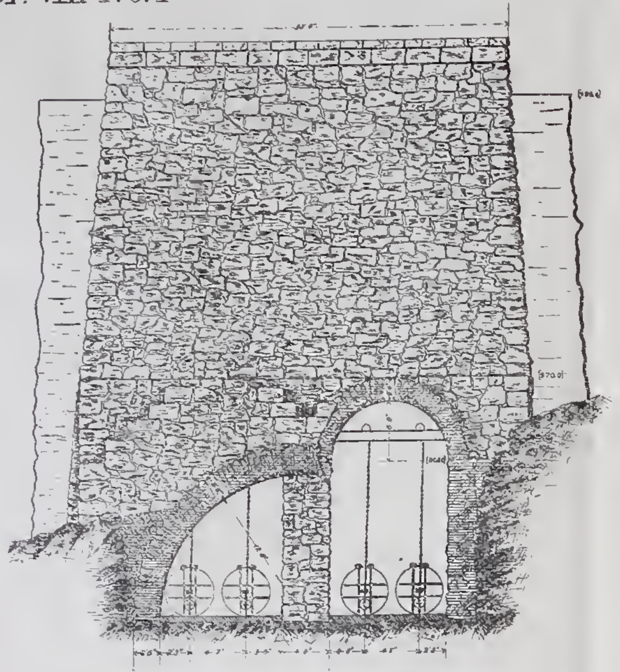
Nov.

THE

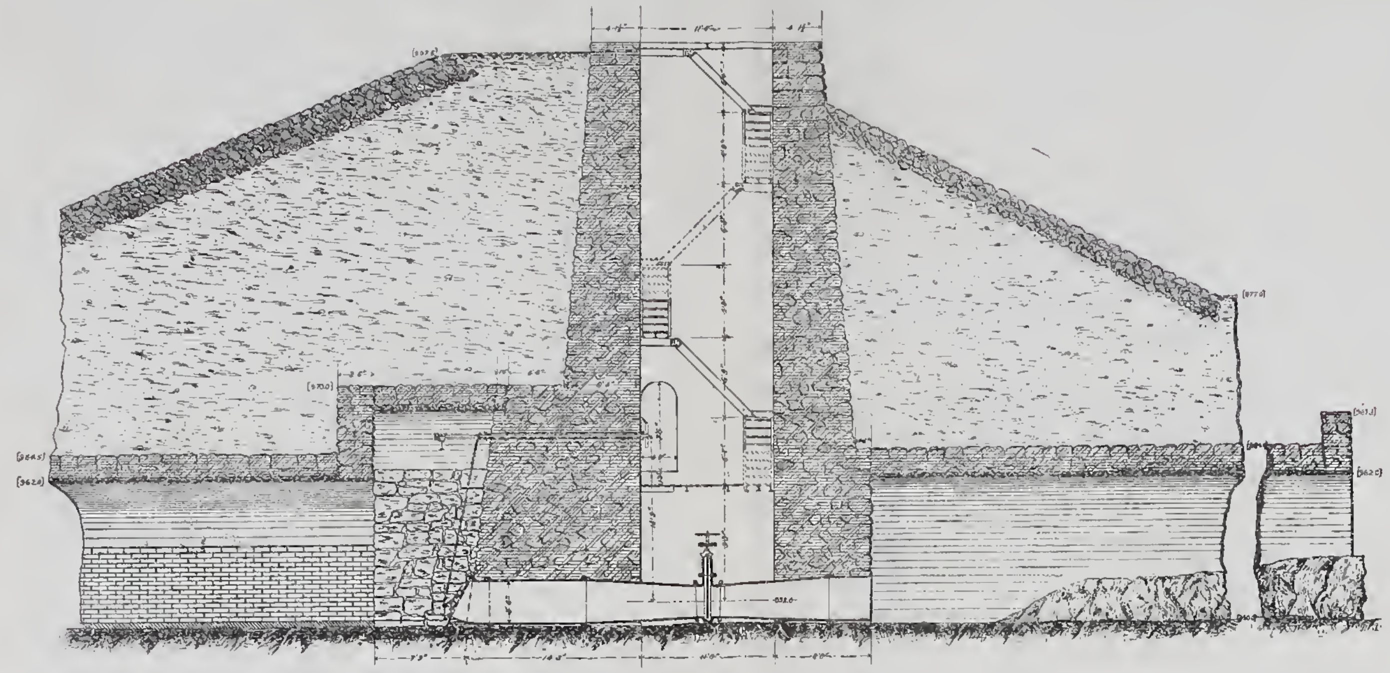
EAST JERSEY WATER COMPANY

CLINTON GATE HOUSE

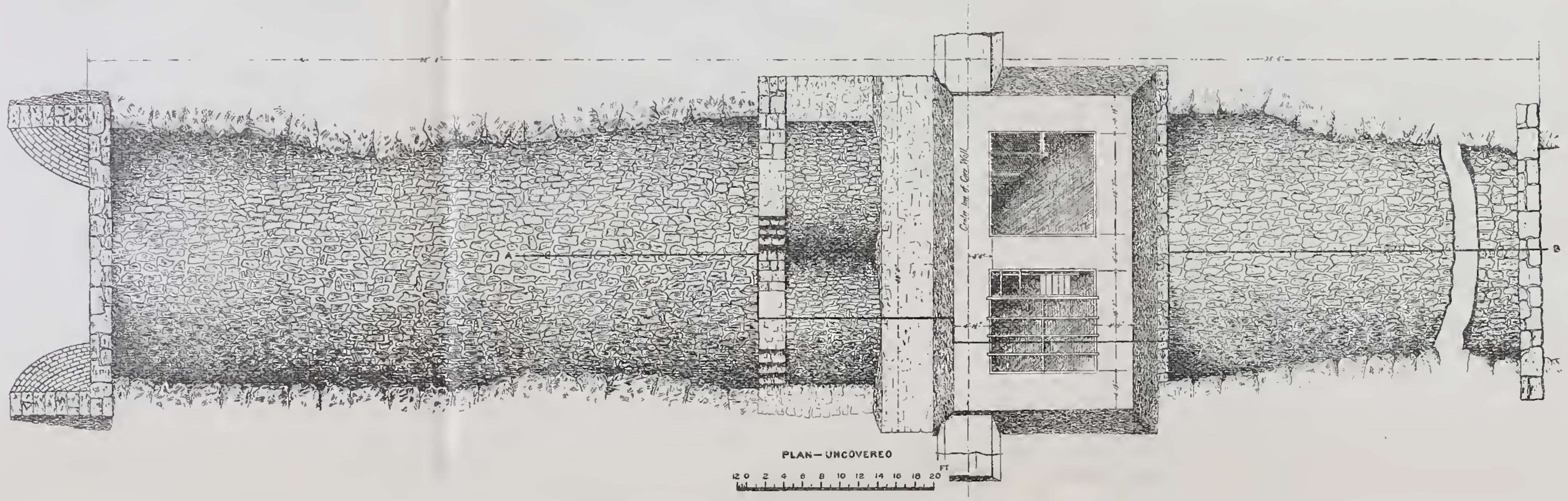
MARCH 1892



UP-STREAM ELEVATION — UNCOVERED

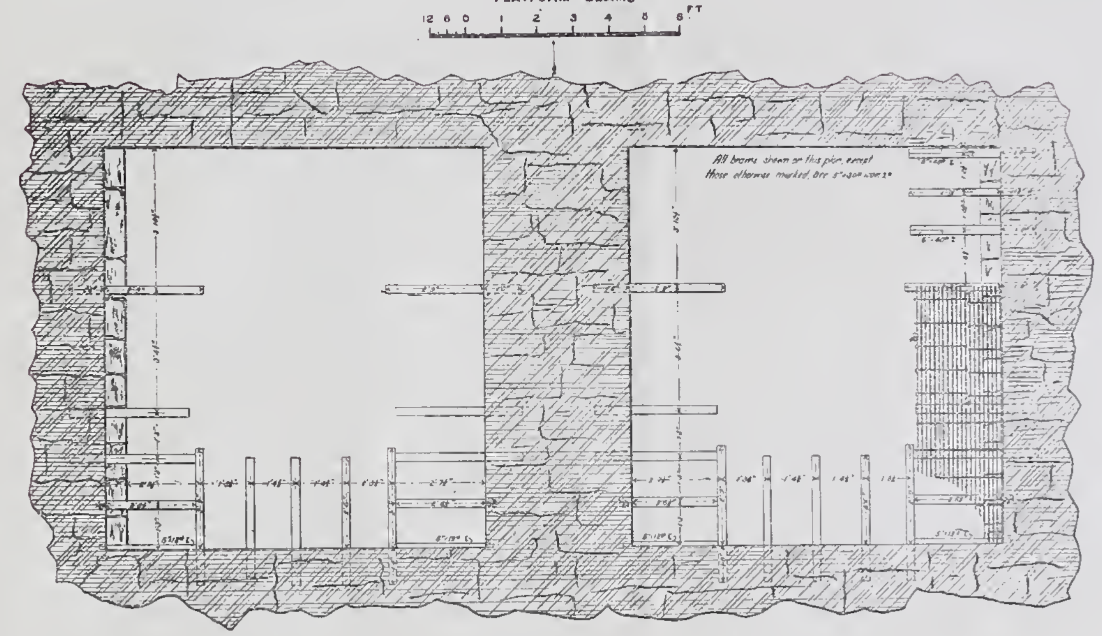


SECTION ON LINE AB

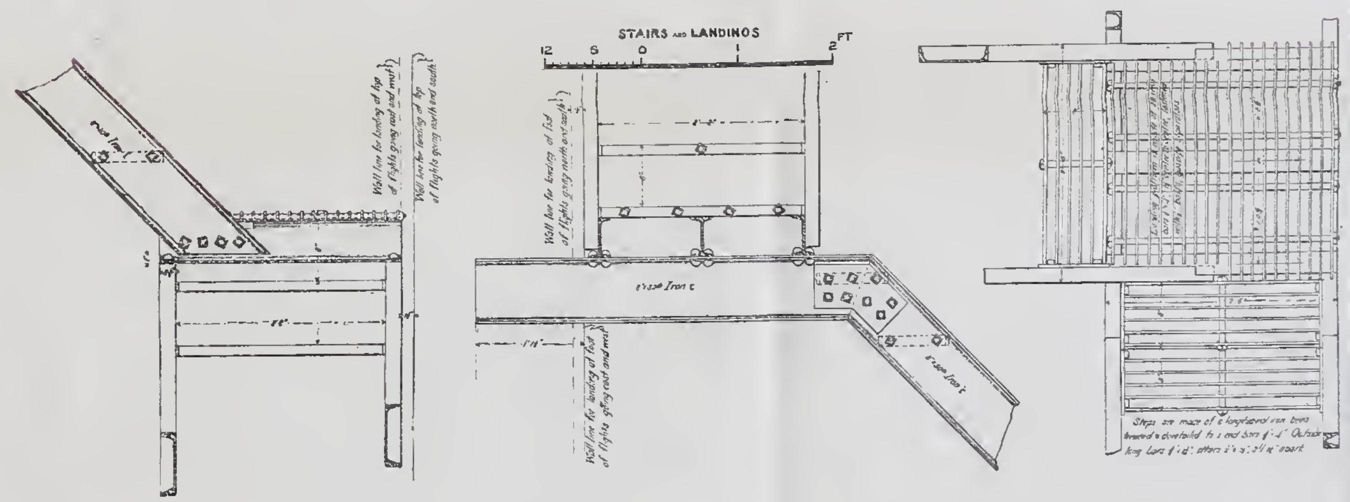


PLAN — UNCOVERED

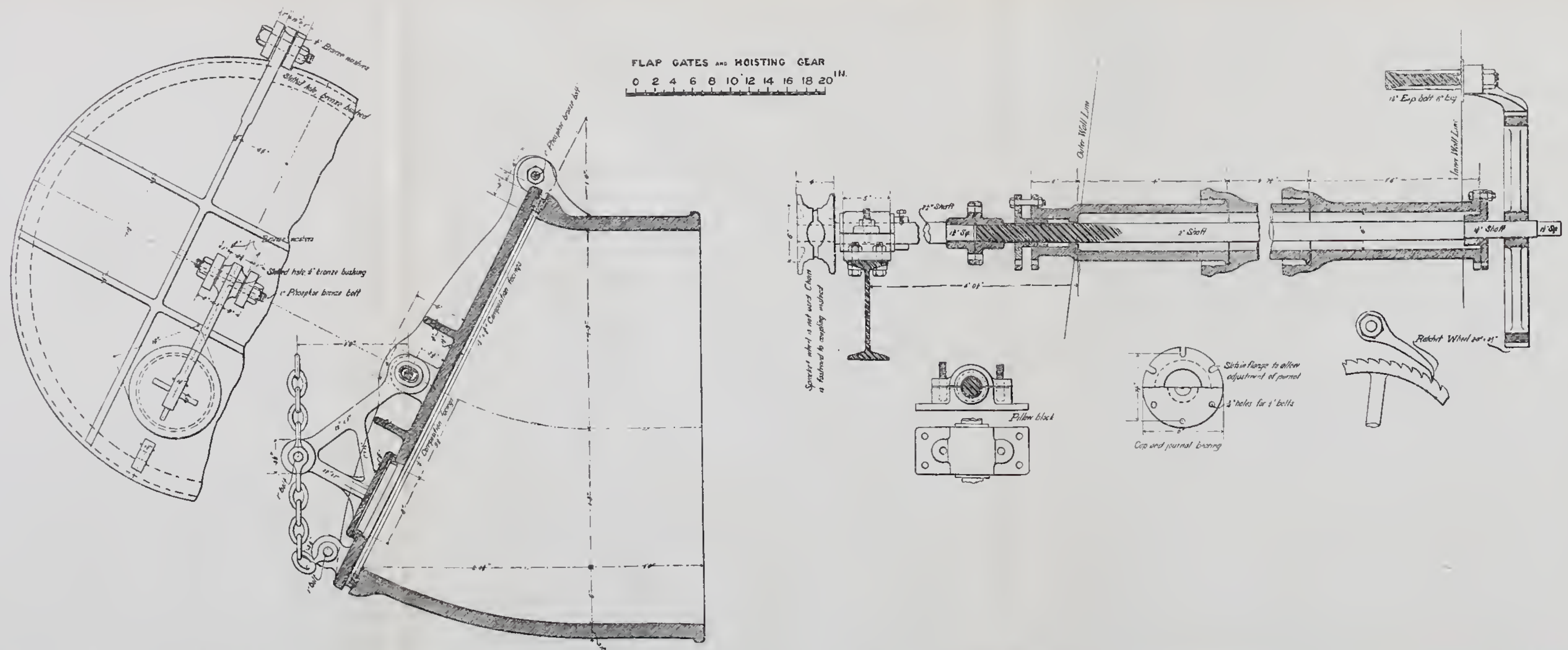
PLATFORM BEAMS



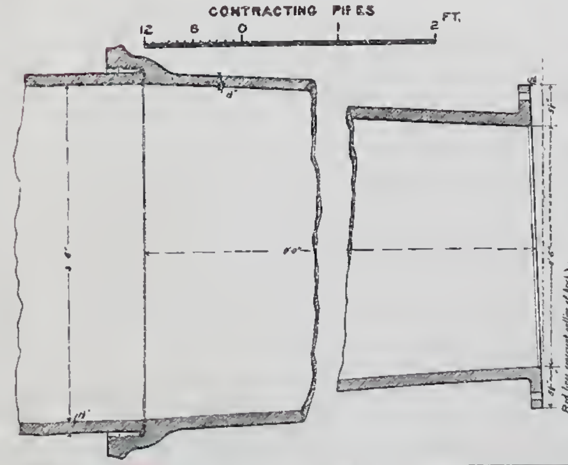
STAIRS AND LANDINGS



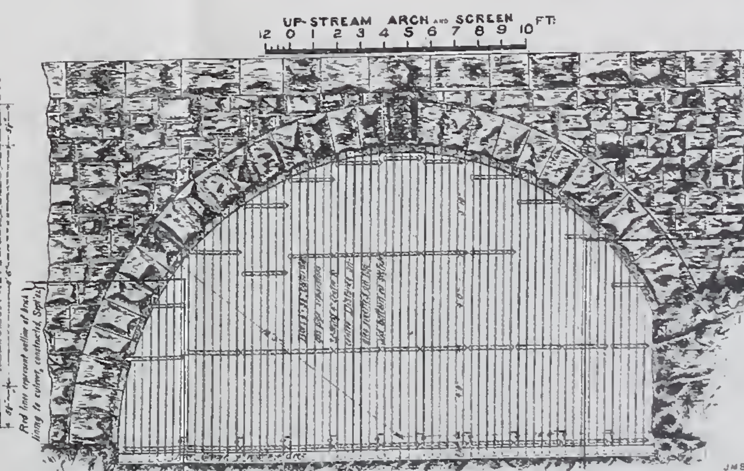
FLAP GATES AND HOISTING GEAR

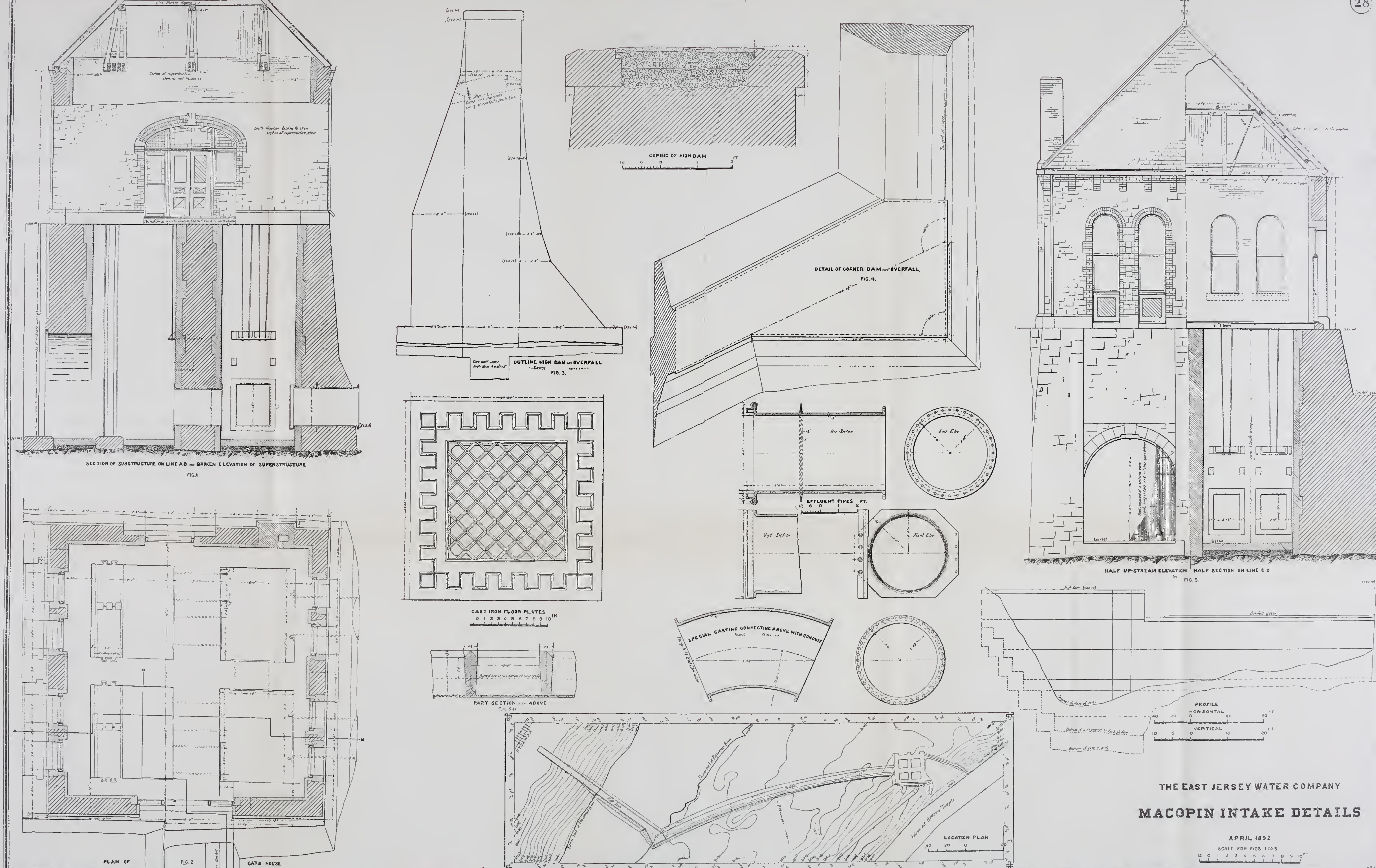


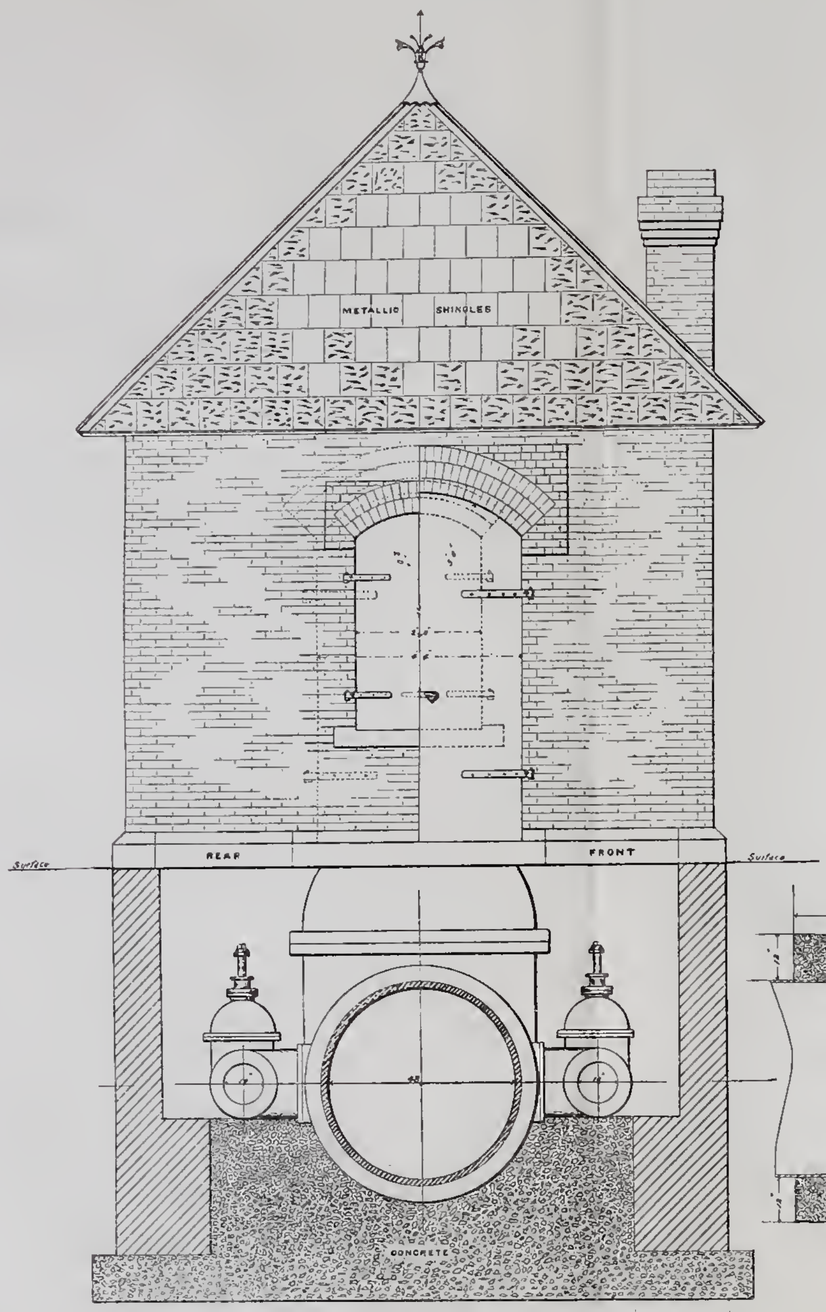
CONTRACTING PIPES



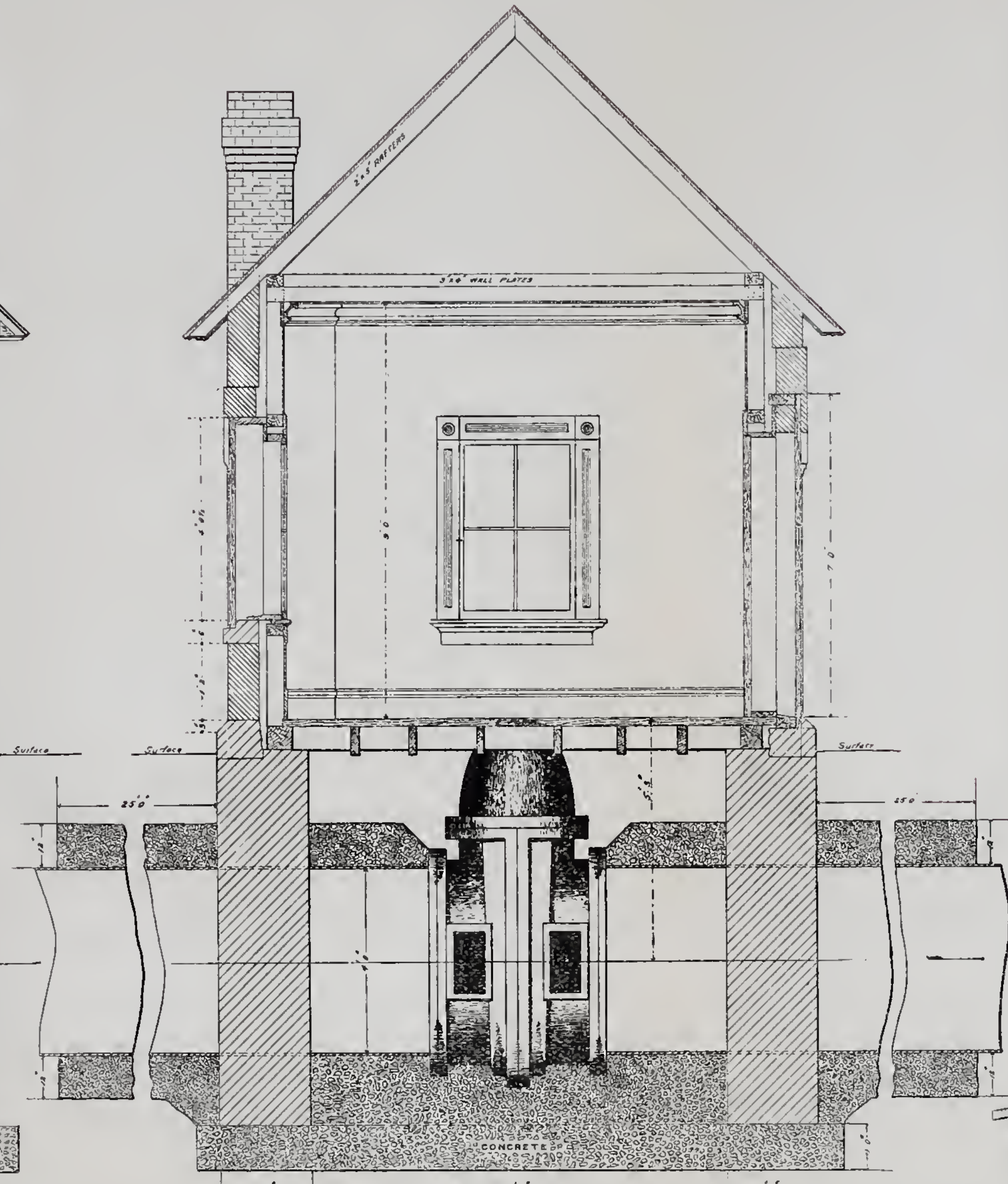
UP-STREAM ARCH AND SCREEN



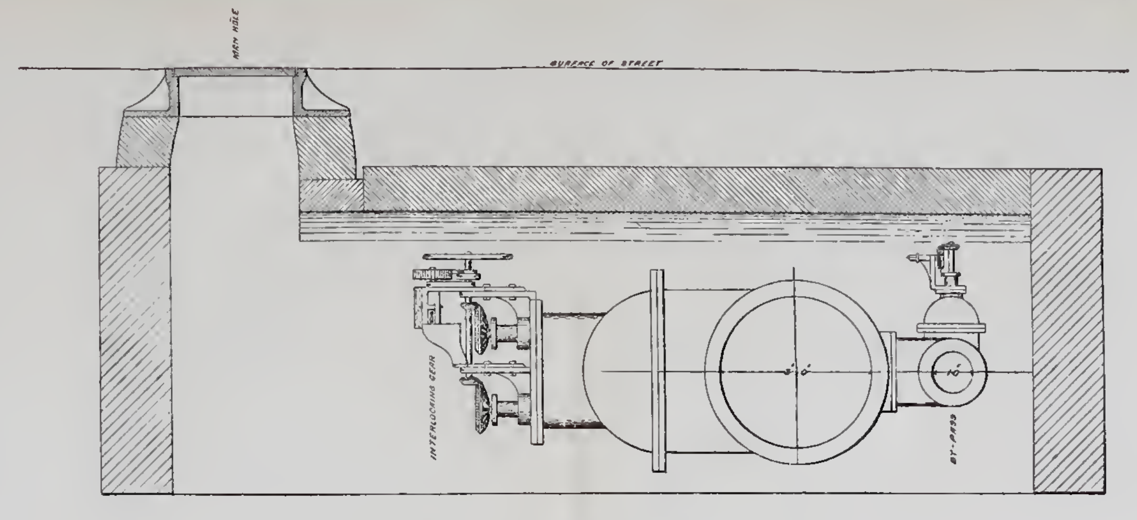

SECTION OF SUBSTRUCTURE ON LINE A.B. AND BROKEN ELEVATION OF SUPERSTRUCTURE
FIG. 1
PLAN OF GATE HOUSE
FIG. 2
OUTLINE HIGH DAM AND OVERFALL
FIG. 3
COPING OF HIGH DAM
DETAIL OF CORNER DAM AND OVERFALL
FIG. 4
CAST IRON FLOOR PLATES
PART SECTION OF THE ABOVE
Full Size
EFFLUENT PIPES
Hor. Section
Vert. Section
End Elev.
Front Elev.
SPECIAL CASTING CONNECTING ABOVE WITH CONDUIT
HALF UP-STREAM ELEVATION HALF SECTION ON LINE C D
FIG. 5
PROFILE
HORIZONTAL
VERTICAL
LOCATION PLAN
THE EAST JERSEY WATER COMPANY
MACOPIN INTAKE DETAILS
APRIL 1892
SCALE FOR FIGS. 1 TO 5



CROSS SECTION & ELEVATION OF 48" CONDUIT GATE HOUSES
FIG. 1.



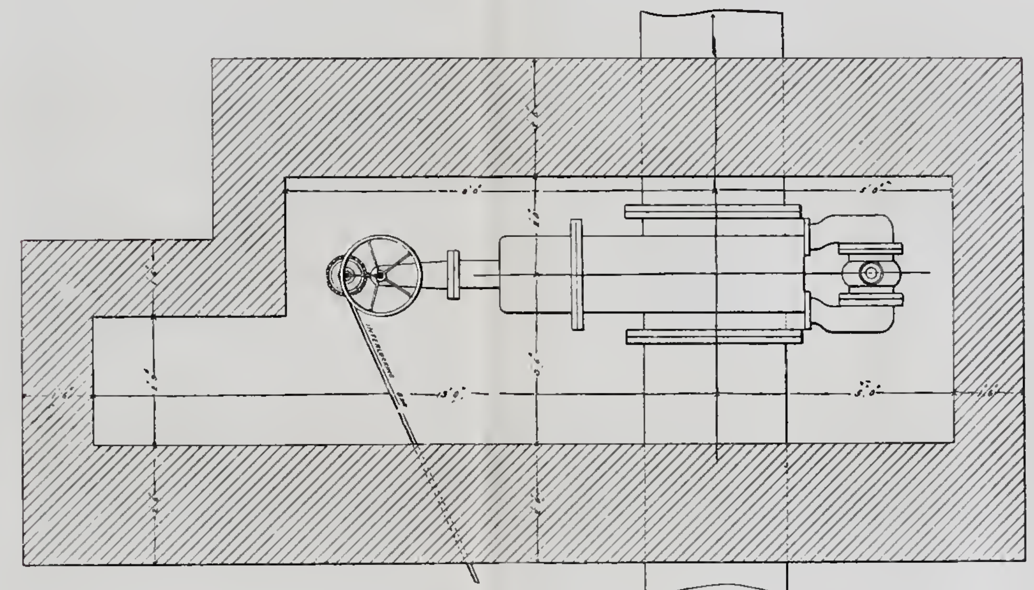
LONGITUDINAL SECTION
FIG. 3.



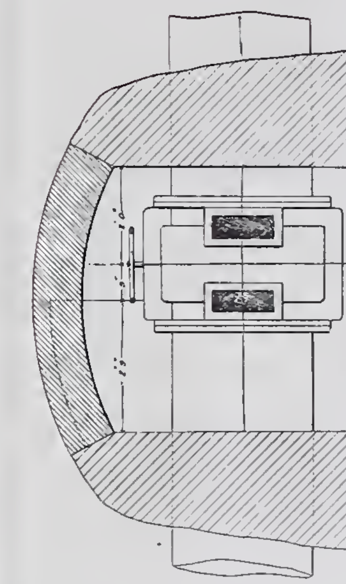
LONGITUDINAL SECTION OF 36" CONDUIT GATE VAULT
FIG. 5.

SCALE FOR FIGS. 1 TO 7

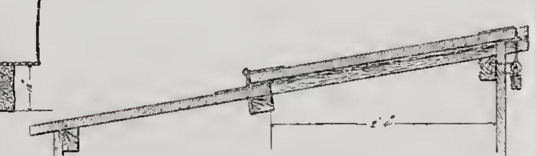
SCALE FOR FIGS. 8 TO 11.



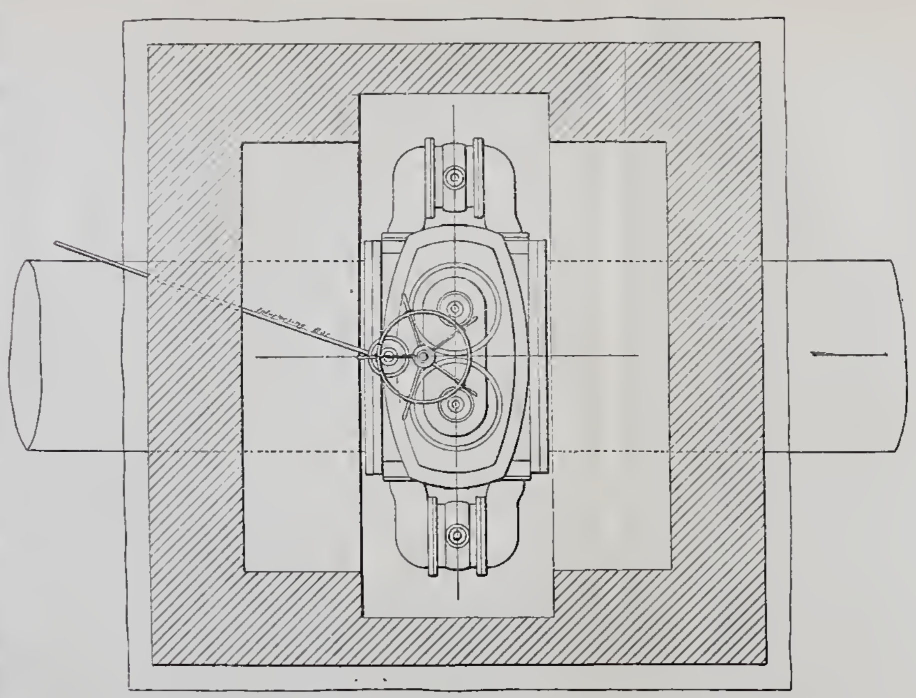
PLAN
FIG. 6.



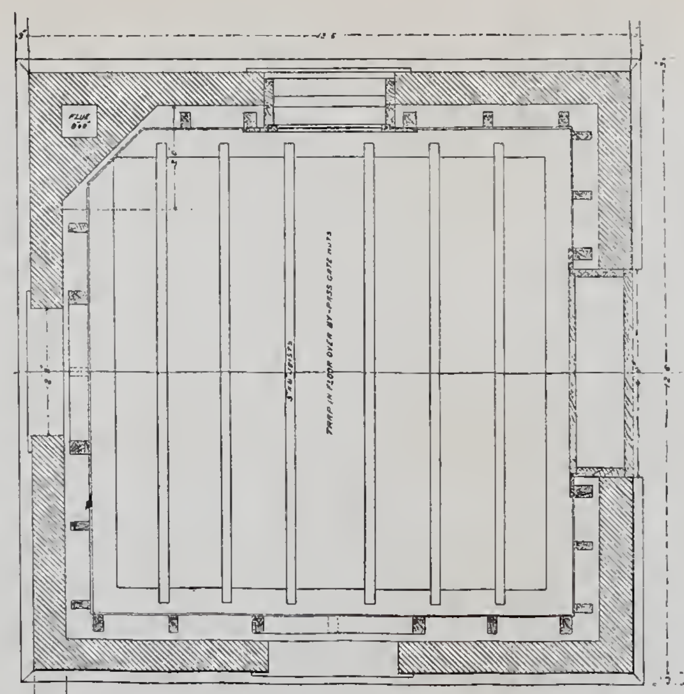
CROSS SECTION
FIG. 7.



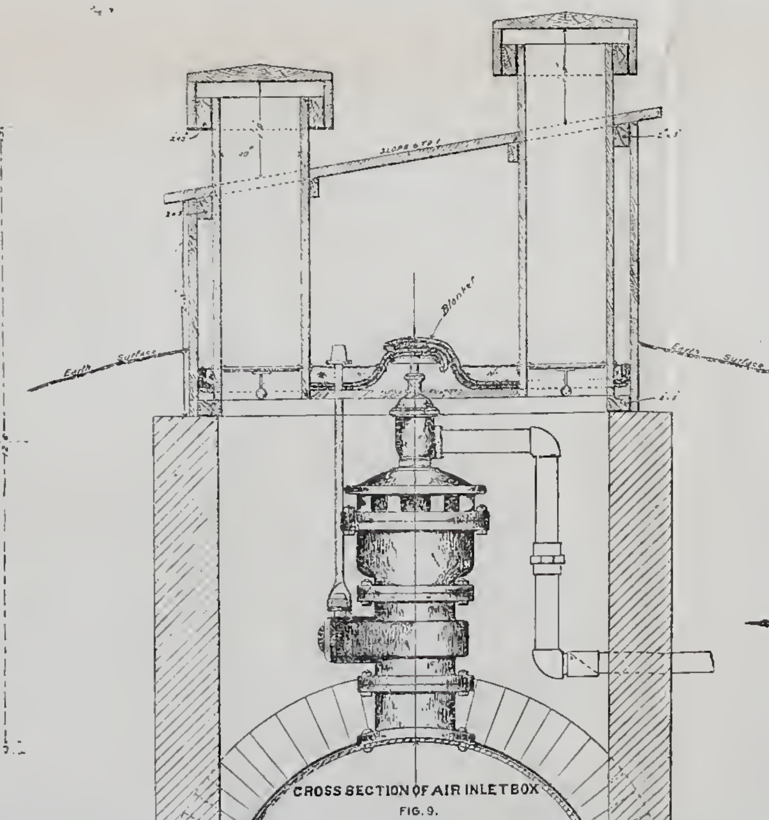
SECTION OF TRAP DOOR
FIG. 8.



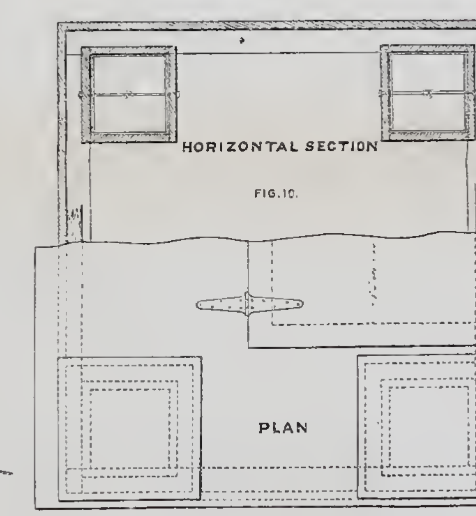
PLAN OF FOUNDATION
FIG. 2.



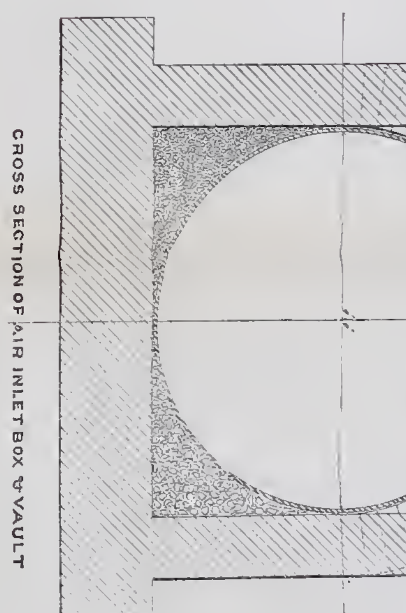
SECTIONAL PLAN
FIG. 4.



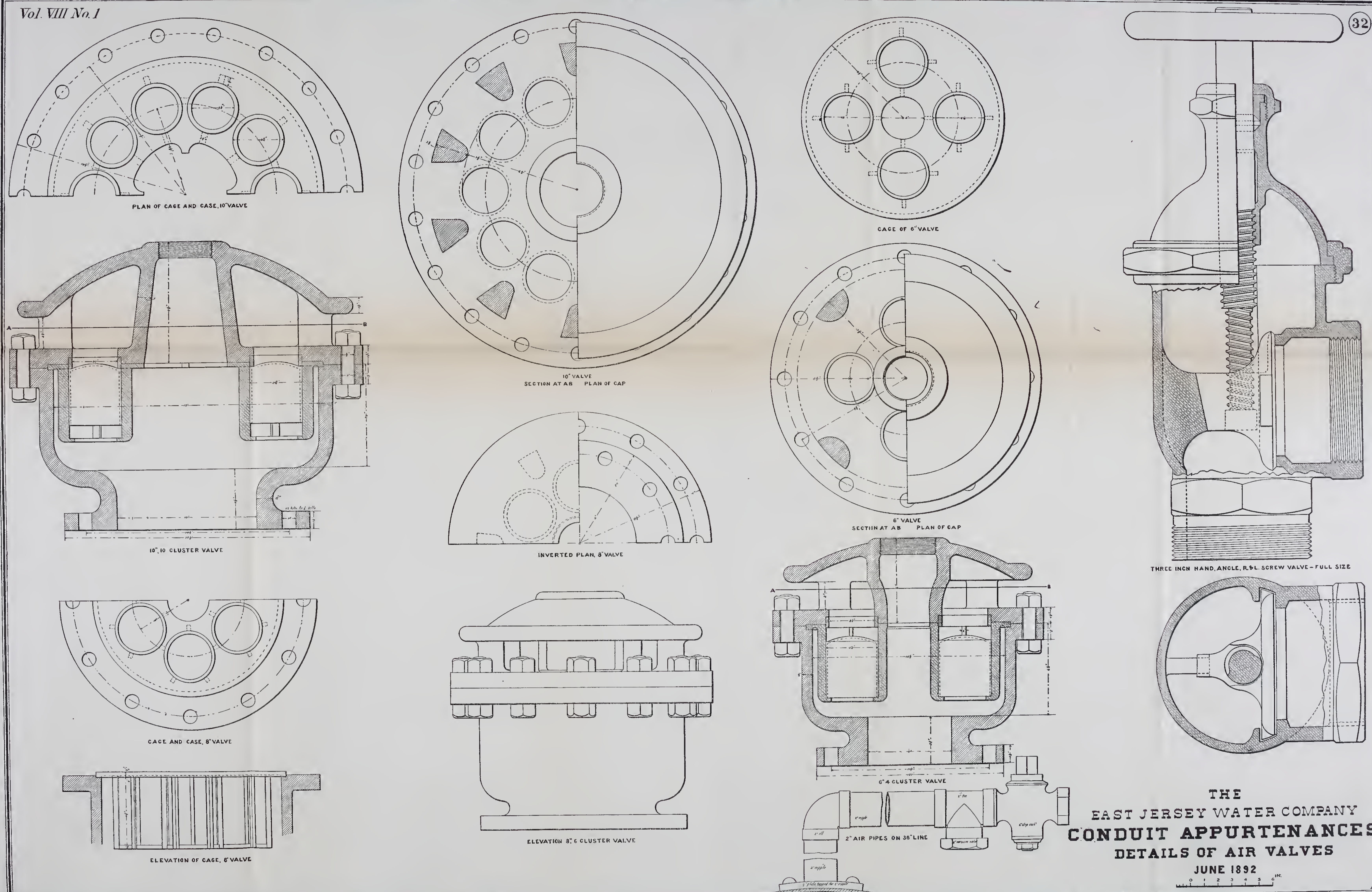
CROSS SECTION OF AIR INLET BOX
FIG. 9.

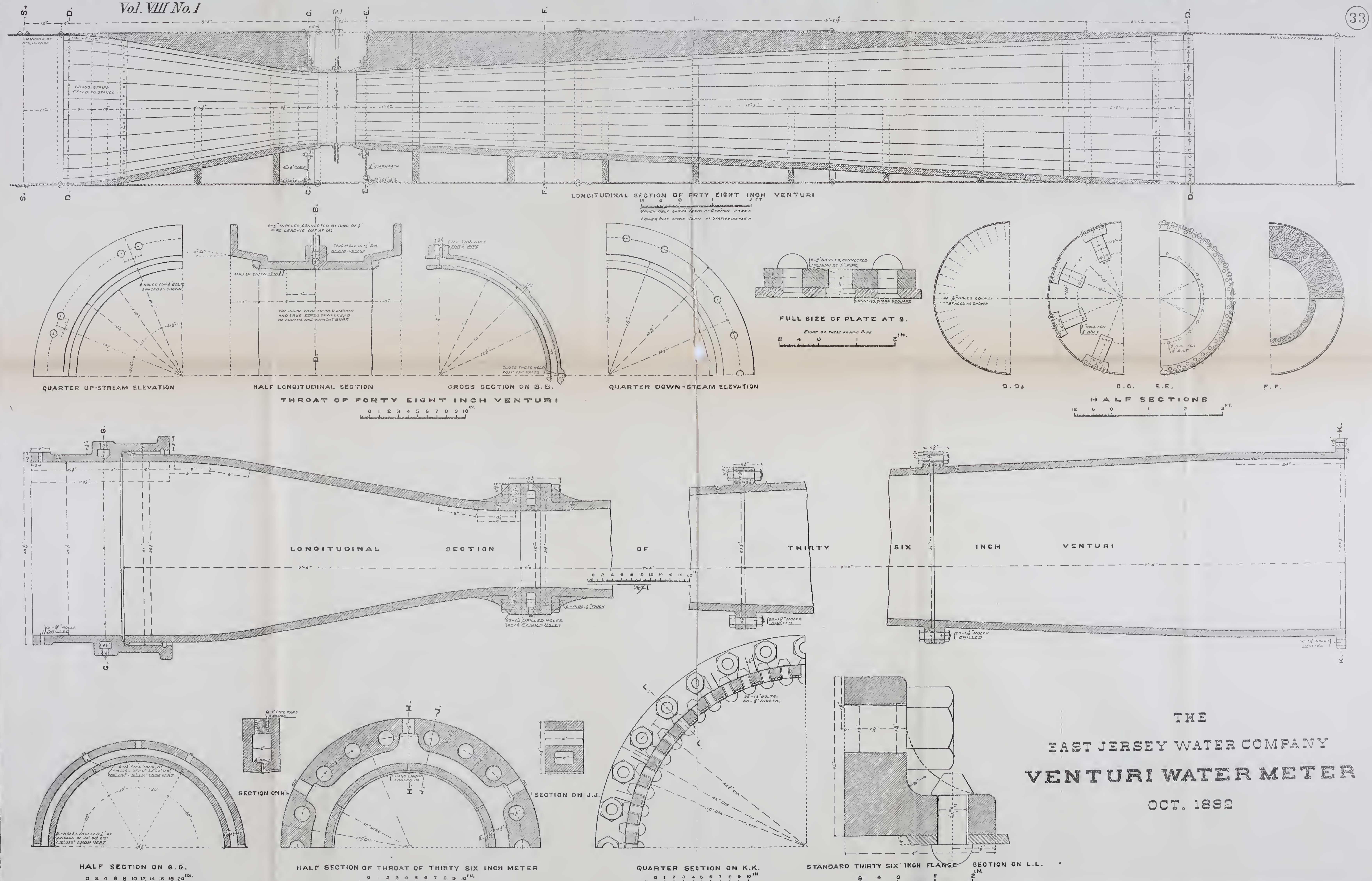


CROSS SECTION OF AIR INLET BOX & VAULT
FIG. 11.



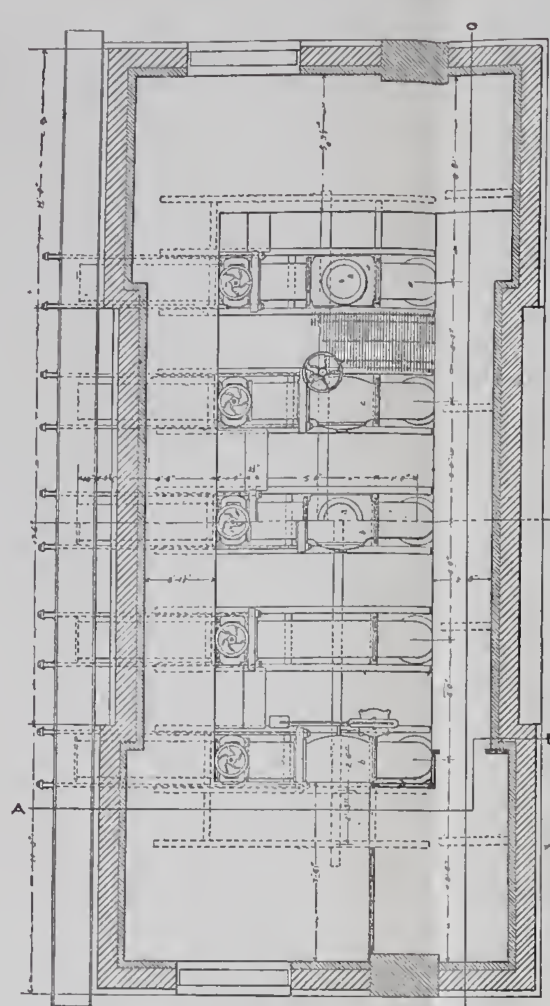
THE
EAST JERSEY WATER COMPANY.
CONDUIT STRUCTURES
JUNE 1892


PLAN OF CAGE AND CASE, 10" VALVE
10" VALVE
SECTION AT AB PLAN OF CAP
CAGE OF 6" VALVE
6" VALVE
SECTION AT AB PLAN OF CAP
THREE INCH HAND, ANGLE, R.&L. SCREW VALVE – FULL SIZE
10", 10 CLUSTER VALVE
INVERTED PLAN, 8" VALVE
CAGE AND CASE, 8" VALVE
ELEVATION 8", 6 CLUSTER VALVE
6", 4 CLUSTER VALVE
2" AIR PIPES ON 36" LINE
ELEVATION OF CAGE, 6" VALVE
THE
EAST JERSEY WATER COMPANY
CONDUIT APPURTENANCES
DETAILS OF AIR VALVES
JUNE 1892
0 1 2 3 4 5 6 INS.

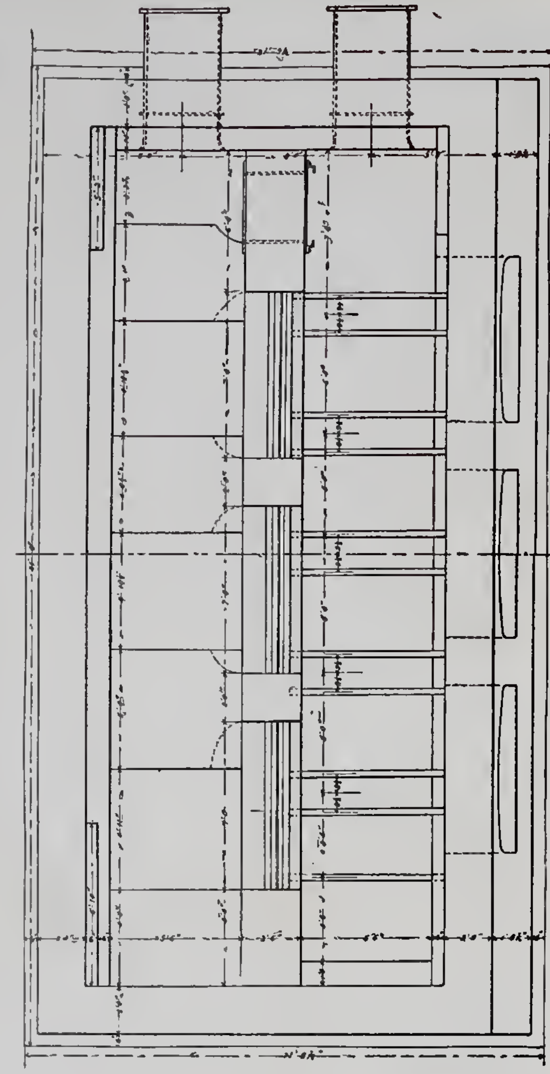


THE
EAST JERSEY WATER COMPANY
VENTURI WATER METER
OCT. 1892

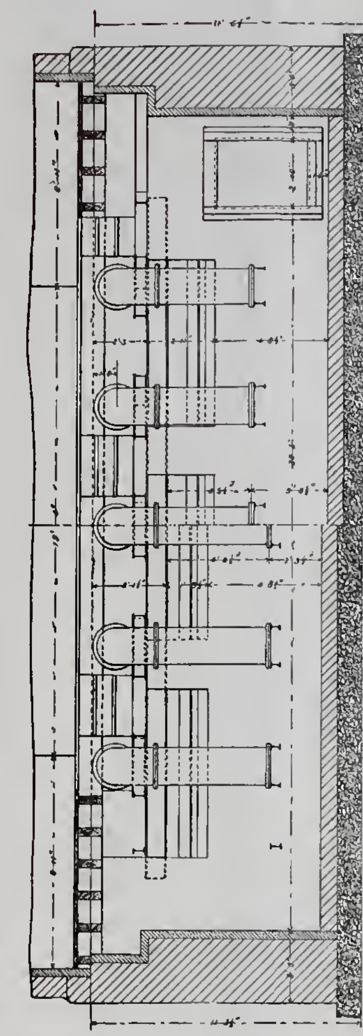
Vol. VIII No. 1.



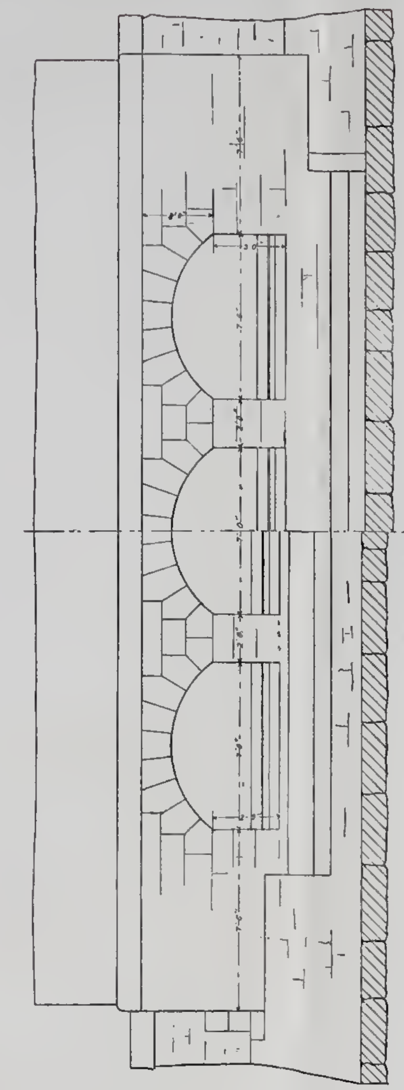
HALF SO. OR. AVE. GATE HOUSE PLAN HALF BELLEVILLE GATE HOUSE
FIG. 1.



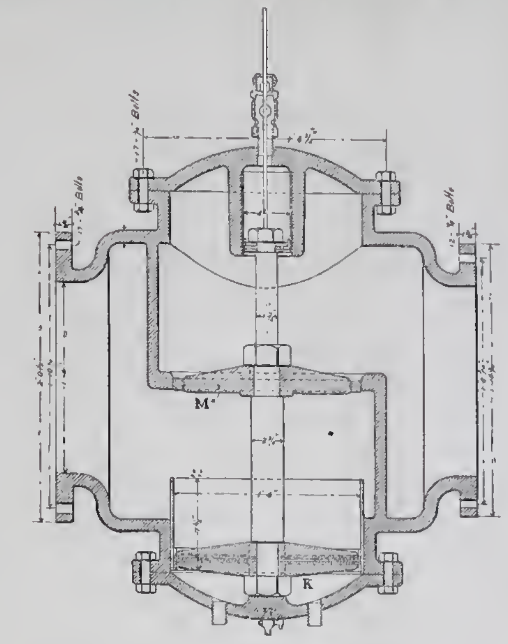
PLAN WITH FLOOR AND PIPES REMOVED
FIG. 2.



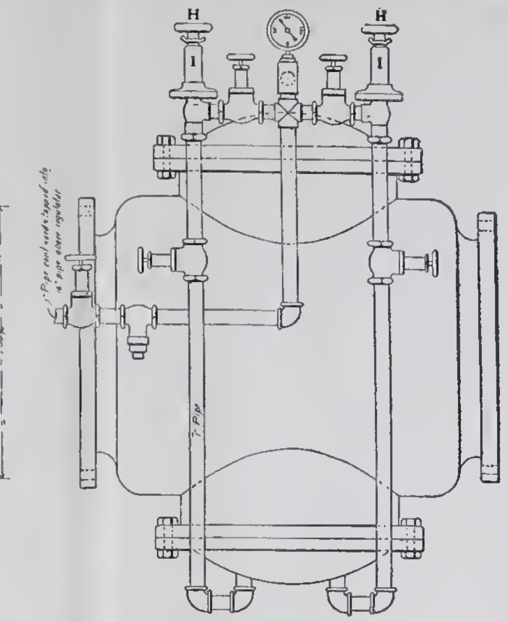
SECTION ON LINE C D
FIG. 3.



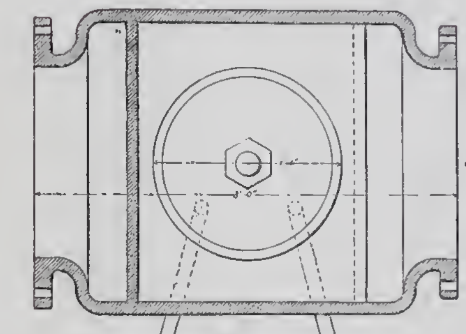
ELEVATION OF RESERVOIR FRONT
FIG. 4.



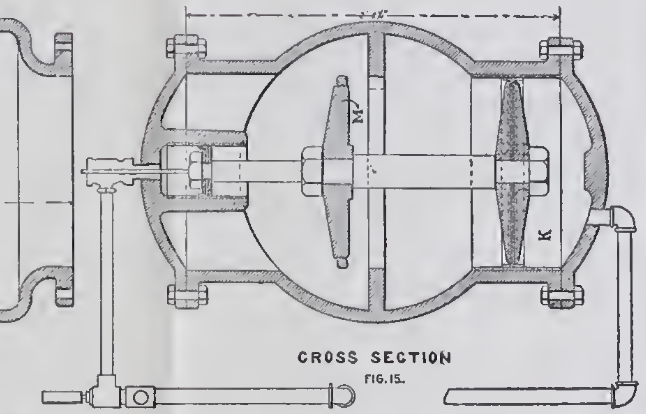
LONGITUDINAL SECTION
FIG. 12.



ELEVATION
FIG. 13.

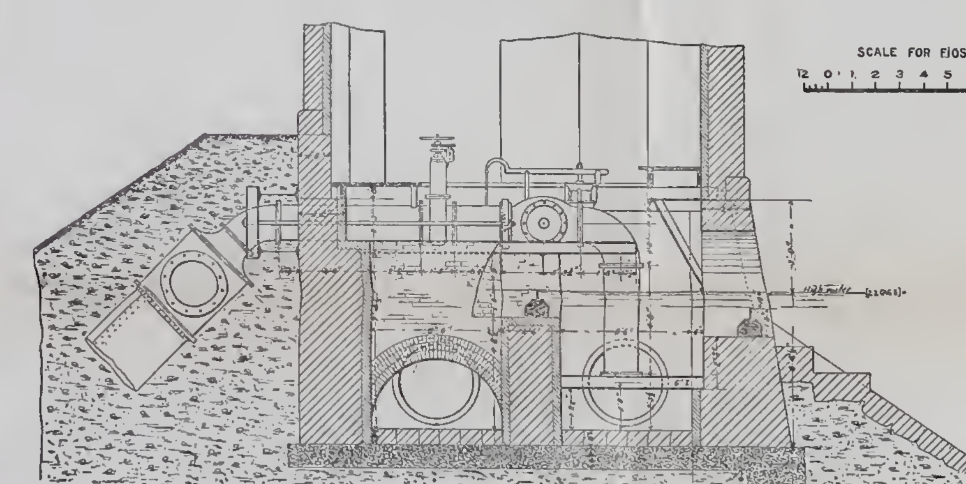


SECTIONAL PLAN
FIG. 14.

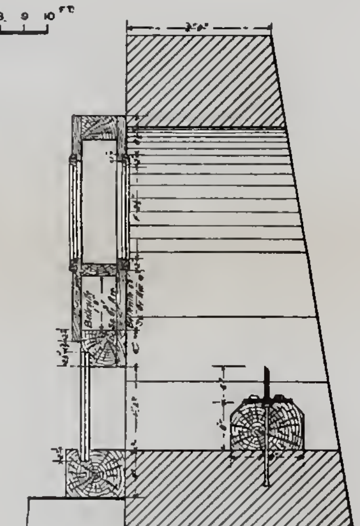


CROSS SECTION
FIG. 15.

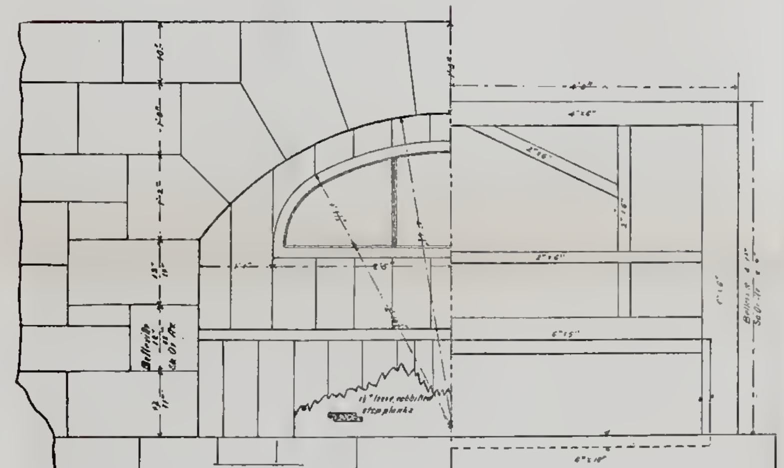
SCALE FOR FIGS. 1 TO 6.



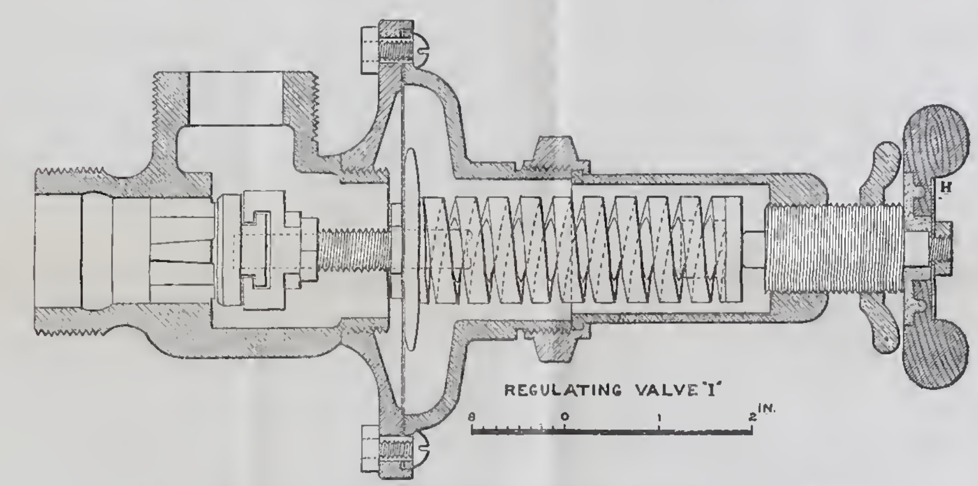
SECTION ON LINE A B – SO. OR. AVE. GATE HOUSE
FIG. 5.



SECTION OF ARCH & AIR CURTAIN
FIG. 7.



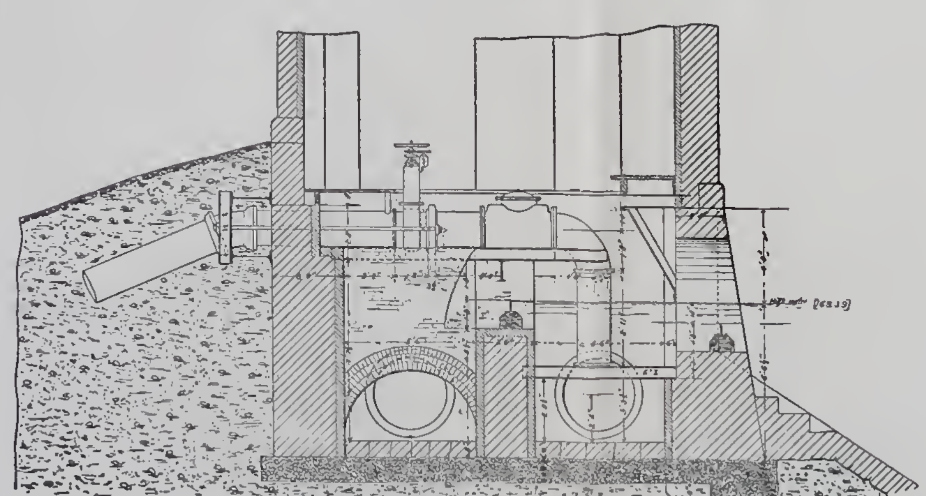
ELEVATION OF ARCH & AIR CURTAIN – WEIR REMOVED
FIG. 8.



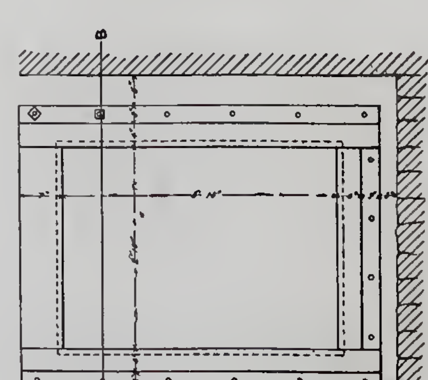
REGULATING VALVE "I"

ROSS VALVE CO. PRESSURE REGULATOR

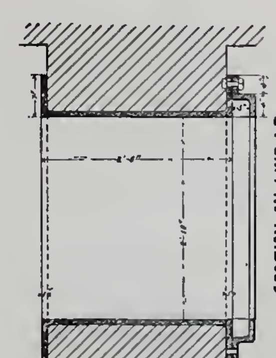
SCALE FOR FIGS. 12 TO 15.



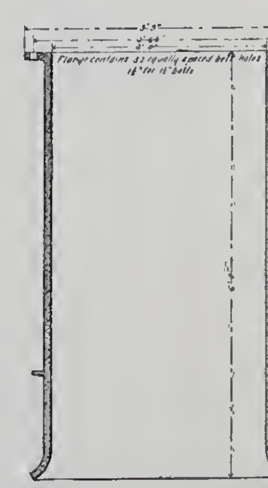
SECTION ON LINE A D – BELLEVILLE GATE HOUSE
FIG. 6.



SPECIAL CASTING NO. 1
FIG. 9.



SECTION ON LINE A B
FIG. 10.



SPECIAL CASTING NO. 2
FIG. 11.

SCALE FOR FIGS. 7 TO 11.

THE EAST JERSEY WATER COMPANY

SUBSTRUCTURE OF GATE HOUSES AT NEWARK RESERVOIRS

NOVEMBER 1892

THE

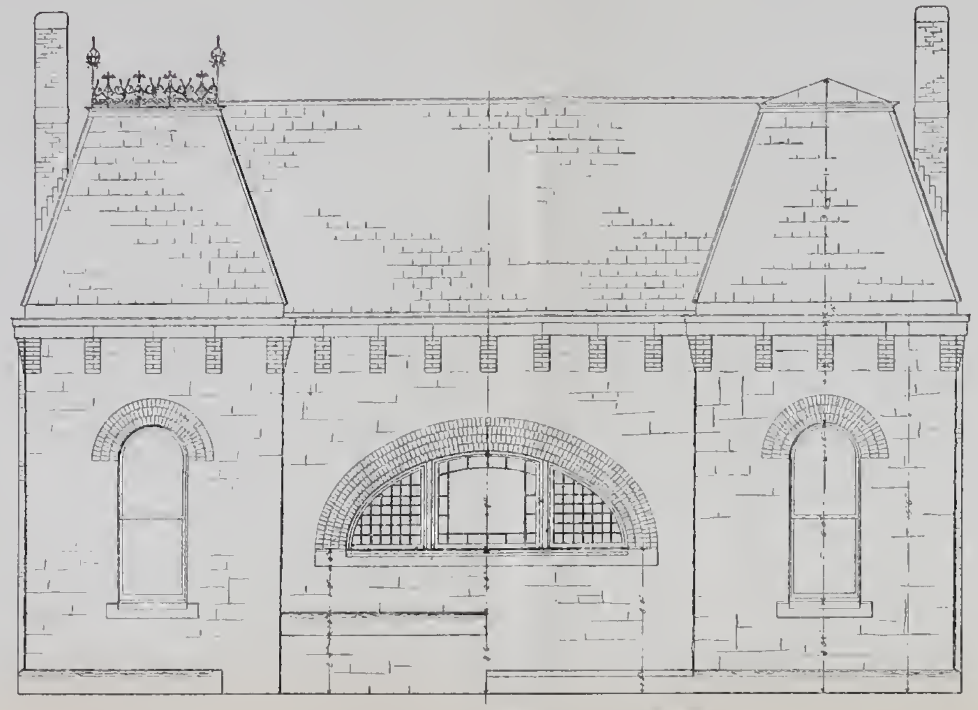
EAST JERSEY WATER COMPANY

SUPERSTRUCTURE OF GATE HOUSES

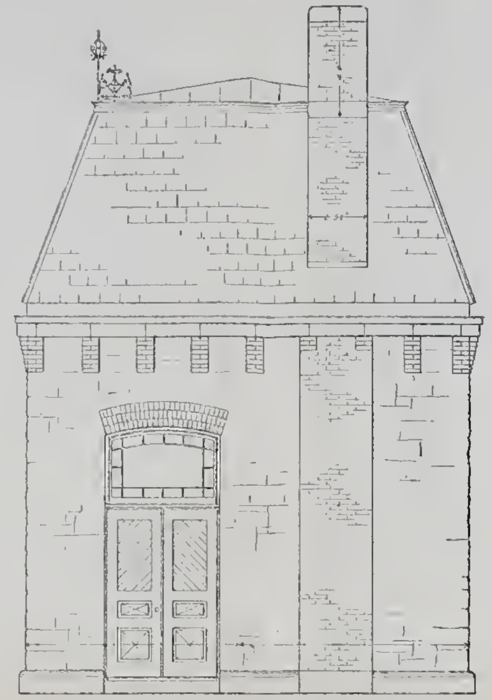
AT

NEWARK RESERVOIRS

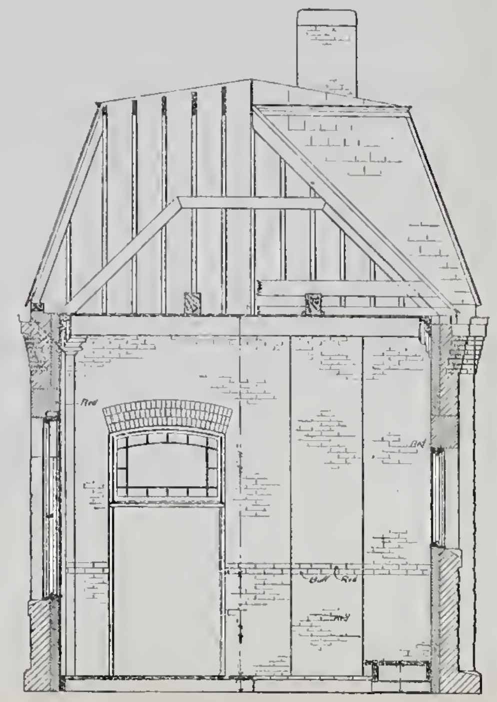
OCTOBER 1892



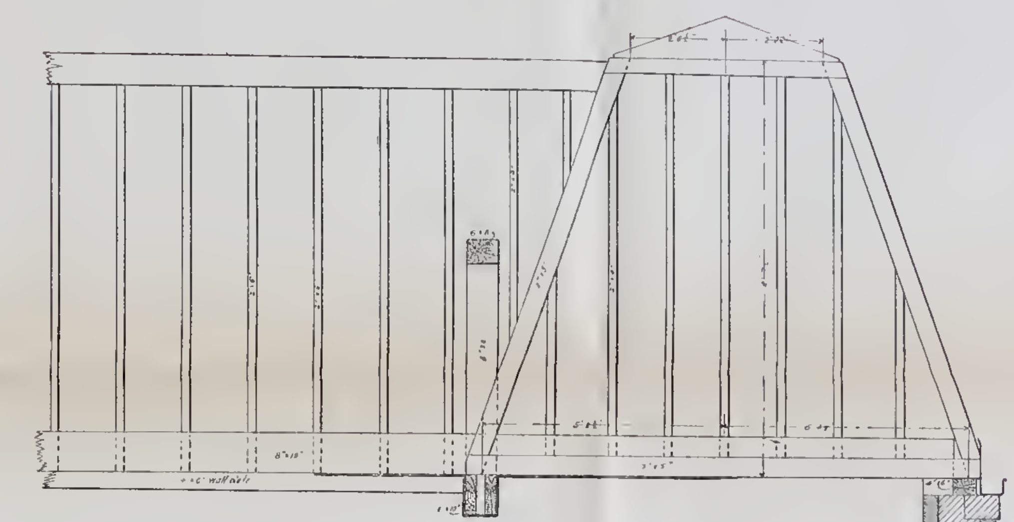
HALF STREET FACE-ELEVATION—HALF RESERVOIR FACE



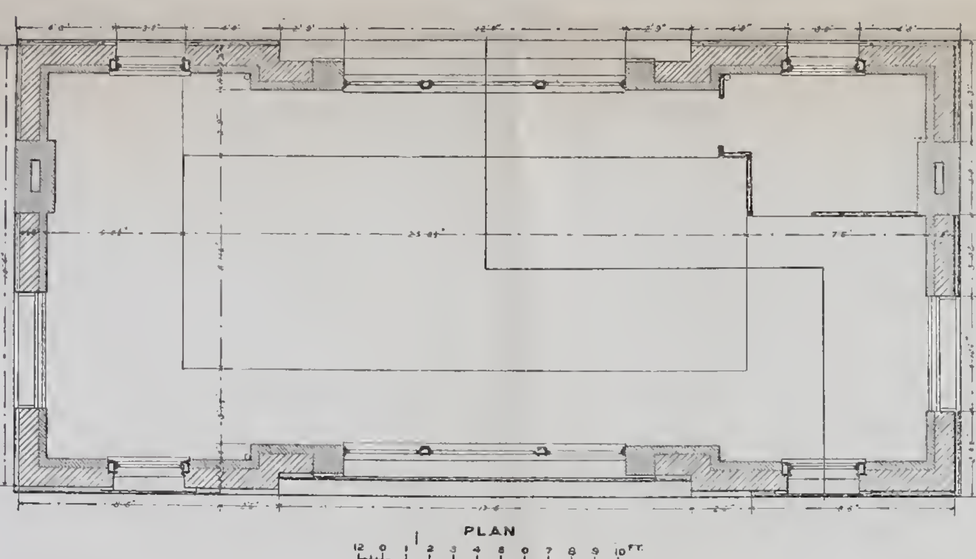
SIDE ELEVATION



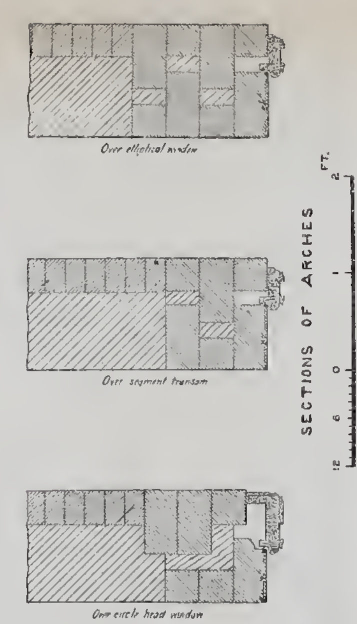
SECTION ON A B

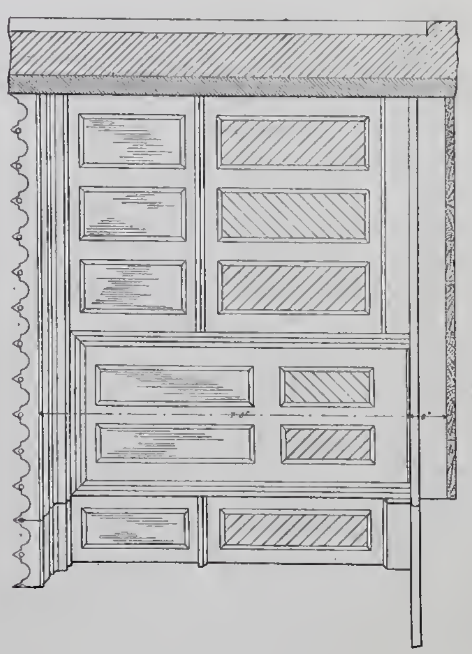


LONGITUDINAL SECTION

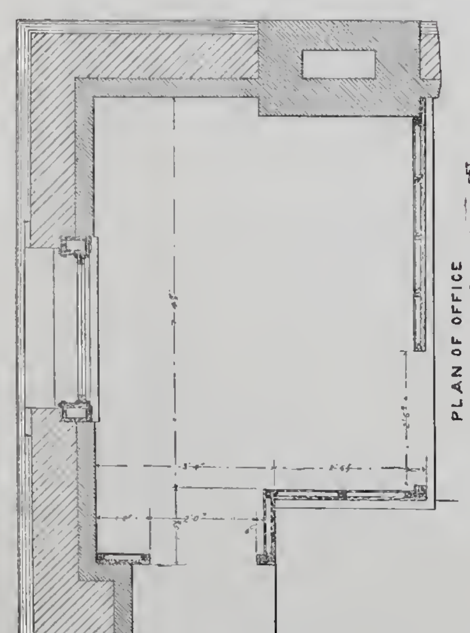


PLAN

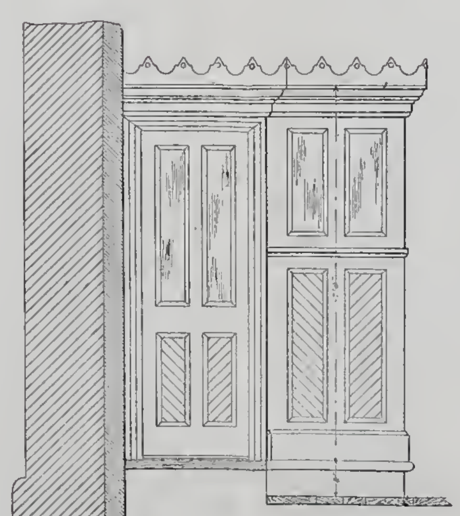




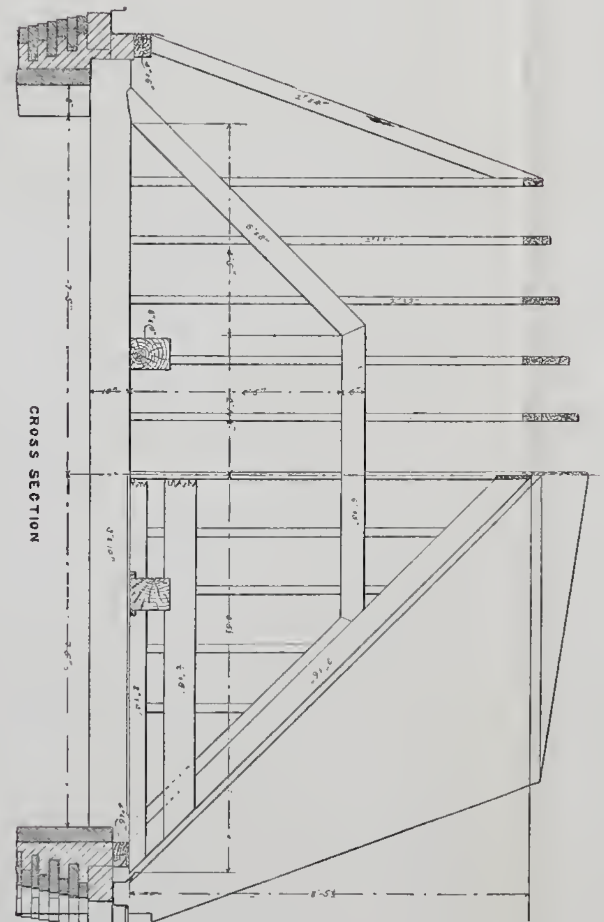
FRONT ELEVATION



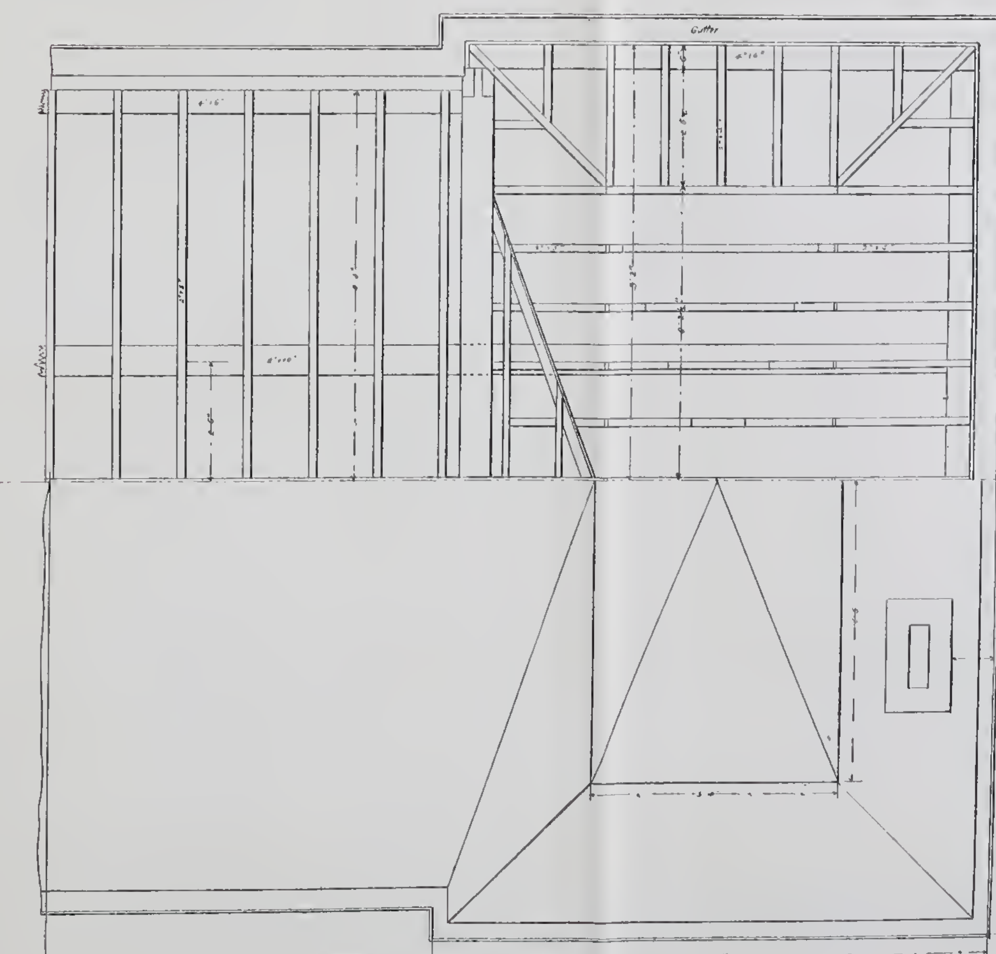
PLAN OF OFFICE



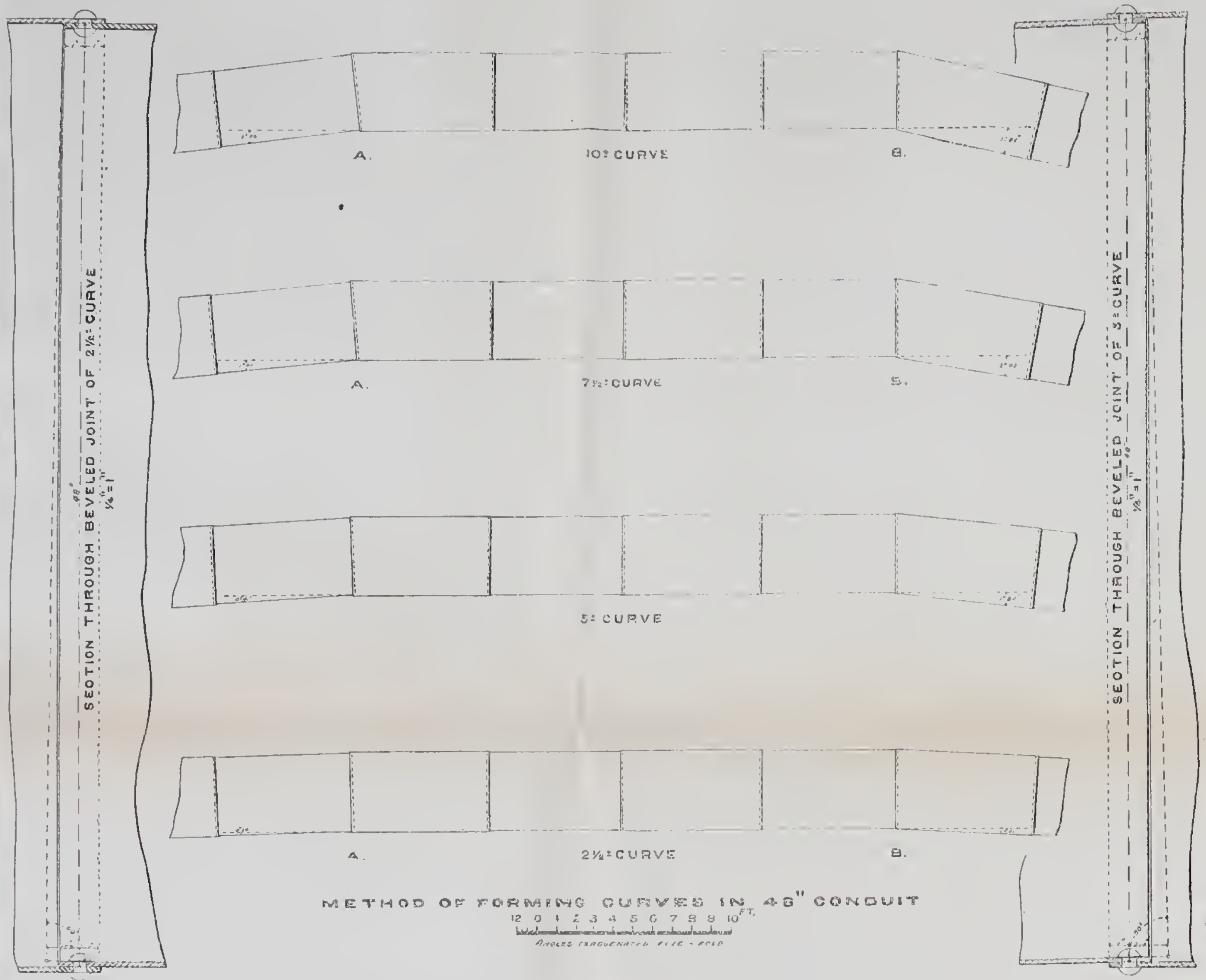
SIDE ELEVATION

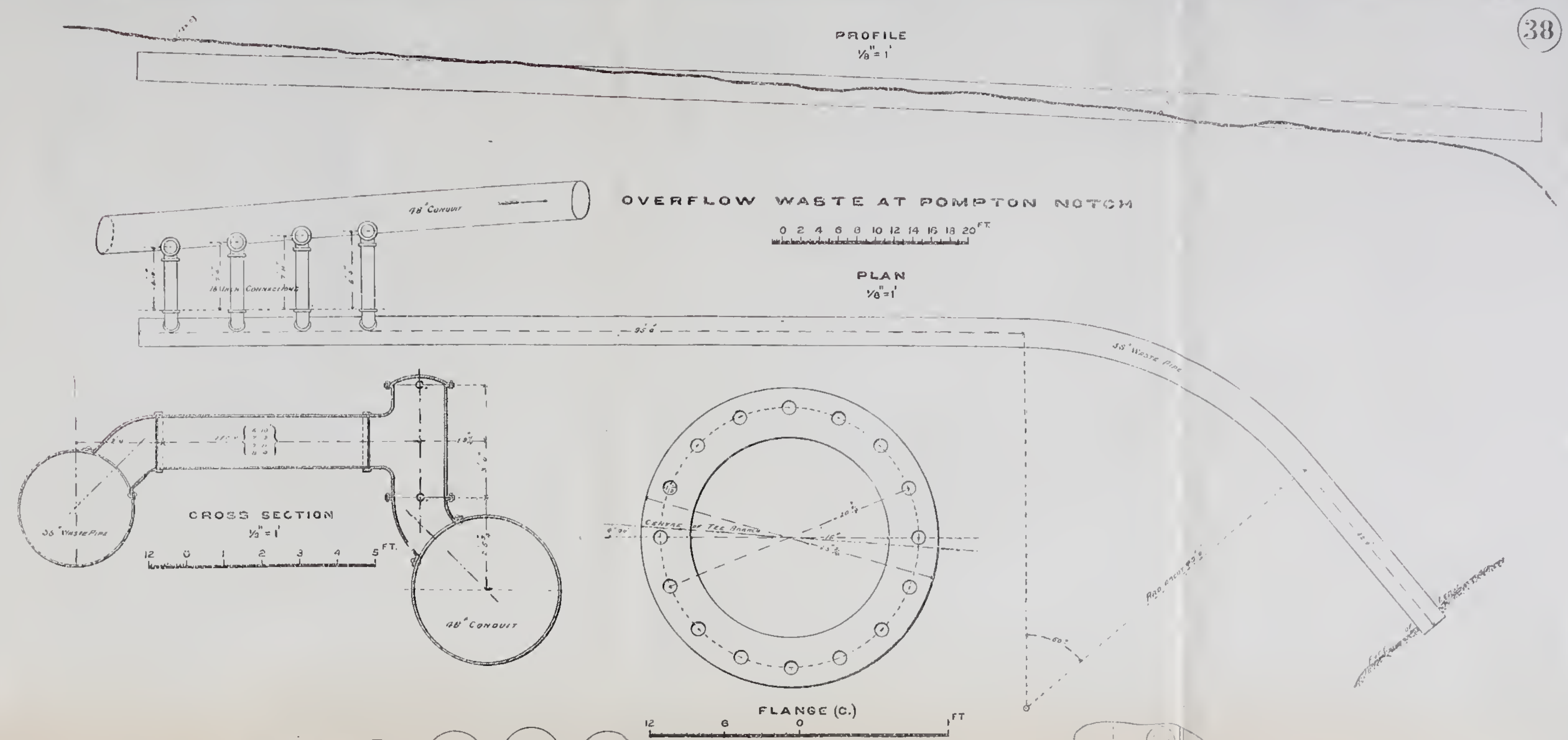


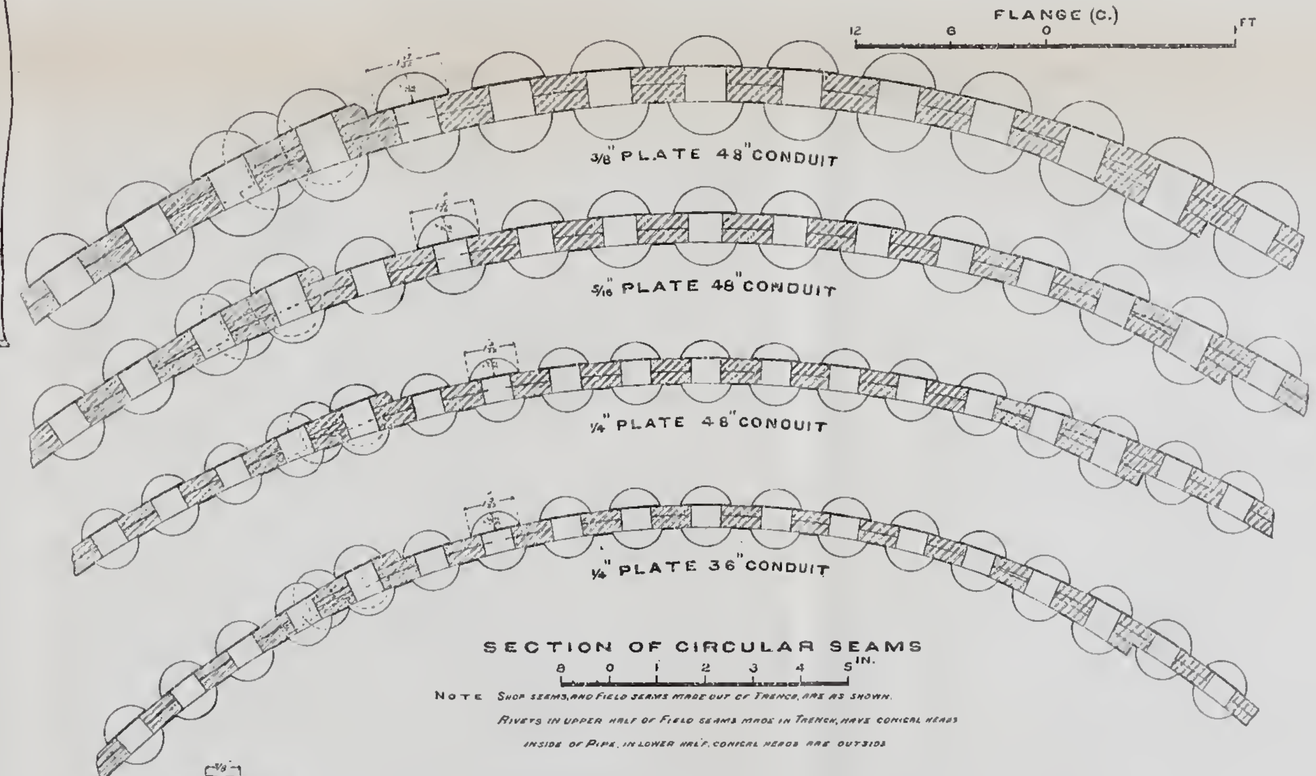
CROSS SECTION



PLAN OF ROOFING







SECTION OF CIRCULAR SEAMS

8 0 1 2 3 4 5 IN.

NOTE. Shop seams, and Field seams made out of Trench, are as shown.

Rivets in upper half of Field seams made in Trench, have conical heads inside of Pipe, in lower half, conical heads are outside.

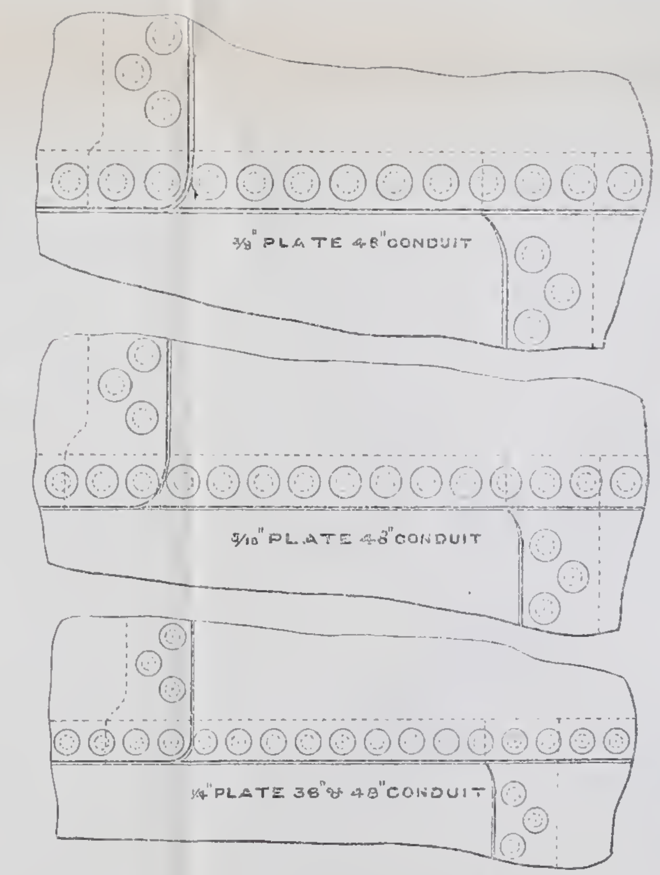
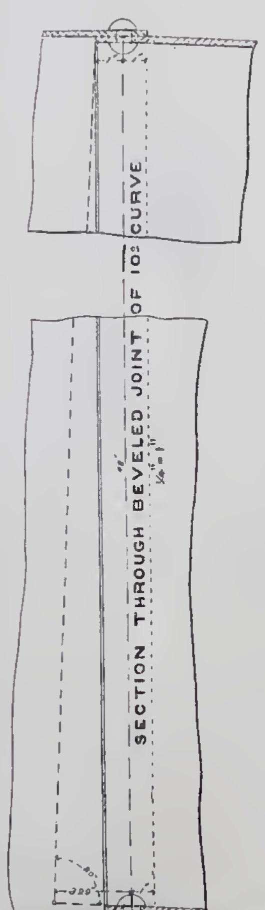


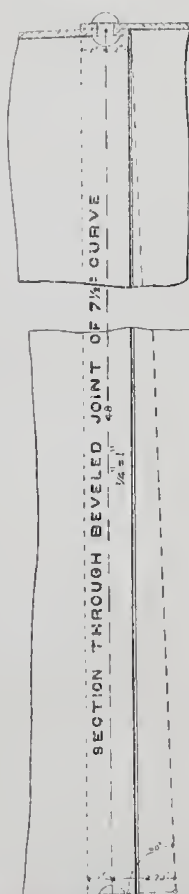
TABLE SHOWING METHOD OF FORMING CURVES IN 48 INCH CONDUIT						
Degree of Curve	Radius	Length of Chord	At B.C. & E.C. (A)		In the Curve (B.)	
			Angle between Chord & Tangent	Offset in 48"	Angle between Chords	Offset in 48"
10°	573.7	2 lengths of pipe (6.22)	1° 21'	1.10"	2° 44'	2.29"
7½°	769.3	" " "	1° 01'	0.46"	2° 03'	1.72"
5°	1146.3	" " "	0° 41'	0.57"	1° 22'	1.14"
2½°	2292.0	" " "	0° 20'	0.30"	0° 41'	0.57"

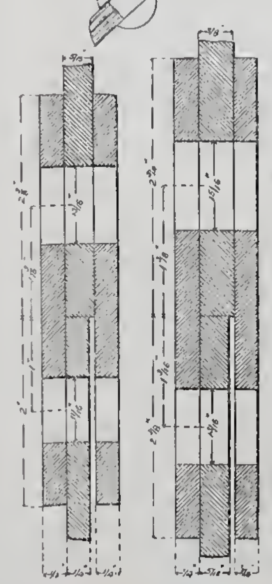
Station of B.C.	Station of E.C.	Radius	Total Angle	Length of Chords	No. of Chords in Curve	At B.C. & E.C. Angle betw. Chord & Tan.	At B.C. & E.C. Offset in 48"	In the Curve Angle betw. Chords	In the Curve Offset in 48"
1110+95.3	1111+31.9	82.0	40° 22'	6.56	4	2° 10'	1.93"	0° 37'	3.87"
1111+59.1	1111+92.3	82.0	23° 03'	[illegible]	5	2° 10'	1.93"	0° 37'	3.87"

NOTE. Vertical Curves are made in the Field by beveled joints cut to suit the angle.

TABLE SHOWING METHOD OF FORMING CURVES AND ANGLES IN 36 INCH CONDUIT										
Station of B.C.	Station of E.C.	Station of Intersection Angle	Radius	Total Angle	Length of Chords	No. of Chords in Curve	At B.C. & E.C. Angle betw. Chord & Tan.	At B.C. & E.C. Offset in 36 inches	In the Curve Angle betw. Chords	In the Curve Offset in 36 inches
1111+47.0	1111+82.7		73.5'	26° 24'	3.80	6	2° 12	1.30"	4° 24	2.77"
		1124+75.0		3° 43'						
		1138+90.3		1° 33'						
		1154+83.5		7° 32'						
1172+19.3	1180+03.0		82.6'	62° 10'	6.91"	14	2° 18	1.00"	4° 37'	2.80"
1180+18.4	1181+02.3		81.6'	62° 10'	6.91'	14	2° 18	1.00"	4° 37'	2.80"
1210+10.7	1211+02.1		82.6'	91° 02	6.26"		2° 30"	1.32"	5° 04'	3.10"
		1217+30.6		4° 08'						
1218+74.2	1213+61.8		64.9'	92° 00'	6.33'	17	2° 03'	1.77"	5° 35'	3.62"
		1231+71.6		5° 40'						
		1297+53.0		5° 12'						
1316+76.8	1317+39.2		72.0'	72° 42	6.41	14	2° 34'	1.61"	5° 03'	3.16"
1317+33.2	1318+38.7		73.0	75° 49'	6.48	14	2° 33'	1.60"	5° 05'	3.13"
1325+40.3	1326+43.0		64.0'	114° 03'	6.72	19	2° 57'	1.85"	5° 58'	3.74"
1330+59.7	1330+84.4		82.6'	23° 30'	3.93	5	2° 03'	1.29"	4° 08	2.53"
1330+84.9	1331+60.3		41.3'	118° 39'	6.19	13	4° 10'	2.70"	8° 31'	5.30"
		1354+91.3		4° 10'						







SECTION OF DOUBLE LAP JOINTS

SCALE: FULL SIZE

NOTE: THESE ARE USED AT CHANGES OF THICKNESS, WHICH CHANGES ARE MADE BETWEEN LARGE SHEETS.

8 4 0 1 2 IN.

TABLE SHOWING METHOD OF RIVETING					
Index	Description	Inches	Inches	Inches	Inches
Miscellaneous Data	Nominal size of Pipe	48	48	48	36
	Thickness of Plate	⅜	5/16	¼	¼
	Size of large Sheets	152¾ x 84	152½ x 84	154⅛ x 88	118⅝ x 84
	Size of small Sheets	153½ x 88	123¾ x 88	153⅜ x 84	115⅞ x 84
	Inside diameter of small Ring	47½	47⅝	47.4	36
	Inside diameter of large Ring	48	48	48	36½
	Size of Rivets	⅝	⅝	⅝	⅝
	Size of Rivet Hole	9/16	11/16	11/16	9/16
	Width of Rivet Head	1 3/32	1 3/16	1 7/32	1 3/32
	Height of Rivet Head	15/32	⅜	15/32	15/32
Data for Circular Seams	Number of Rivets per Seam	120	84	72	74
	Circumference of Large Sheets	151.581	151.778	151.575	115.681
	Circumference of Small Sheets	149.833	149.717	149.338	113.883
	Rivet Pitch of Large Ring	1.813	1.807	2.053	1.521
	Rivet Pitch of Small Ring	1.938	1.782	2.220	1.938
	Distance from centre of Rivet to edge of Plate	1	1 3/16	1 ⅛	1
	Lap of Sheets at Circular Seam	2	2 ⅜	2 ¼	2
Data for Longitudinal Seams	Number of Rivets in first Row	33	29	25	33
	Number of Rivets in Second Row	34	28	24	34
	Total No. of Rivets exclusive of Circular Seam	69	57	49	69
	Rivet Pitch of both Rows	2.277	2.221	3.125	2.277
	Distance between Rows	1 ⅜	1 5/16	1 5/16	1 ⅜
	Diagonal Pitch	1.557	1.908	2.081	1.557
	Distance from Pitchline to Edge of Plates	15/16	1 5/32	1 7/32	15/16
	Lap of Sheets at Longitudinal Seam	3	3 ½	4	3

THE

EAST JERSEY WATER COMPANY

CONDUIT DETAILS

NOVEMBER 1892

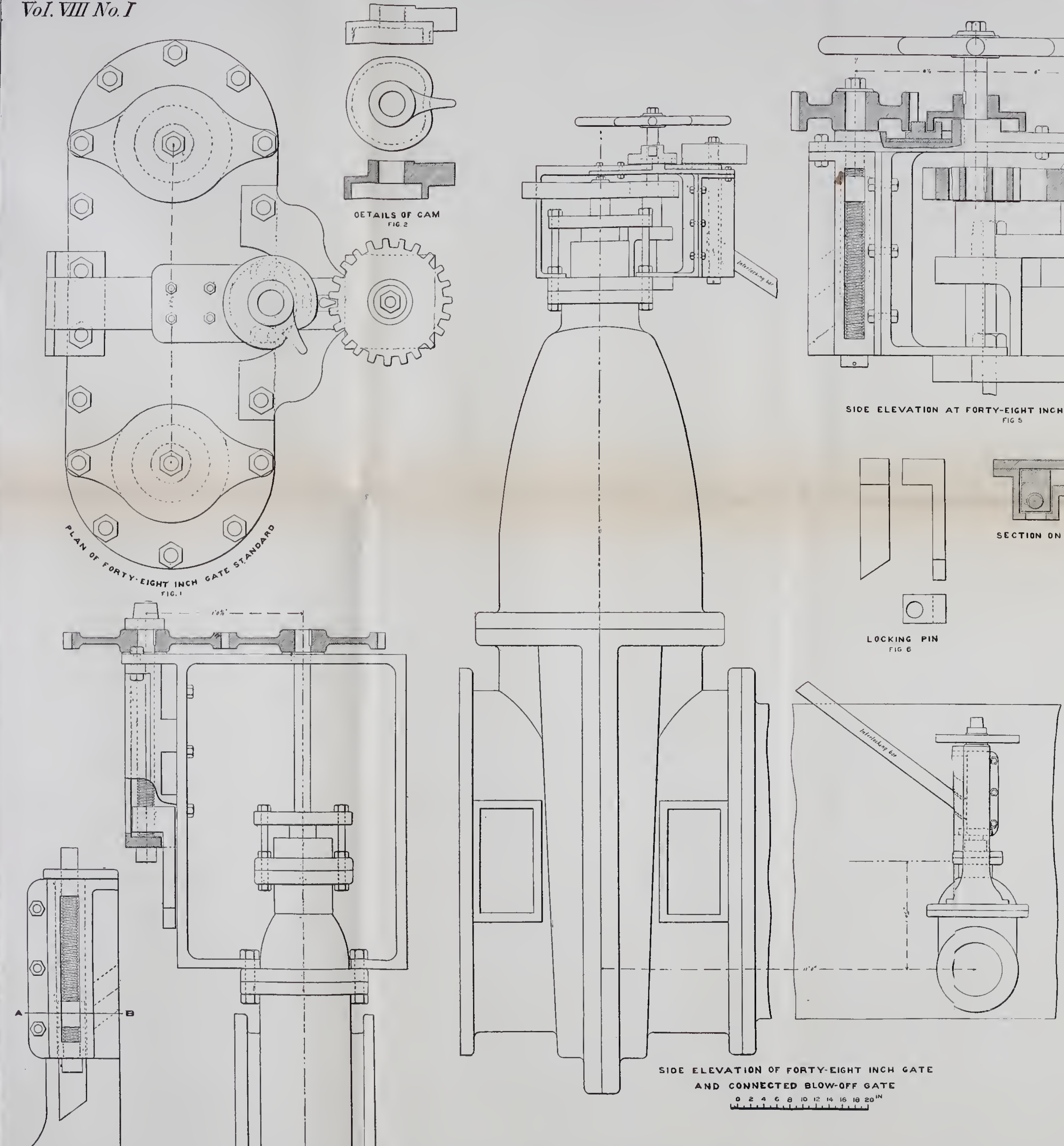
THE

EAST JERSEY WATER COMPANY

CONDUIT APPURTENANCES

DECEMBER 1892

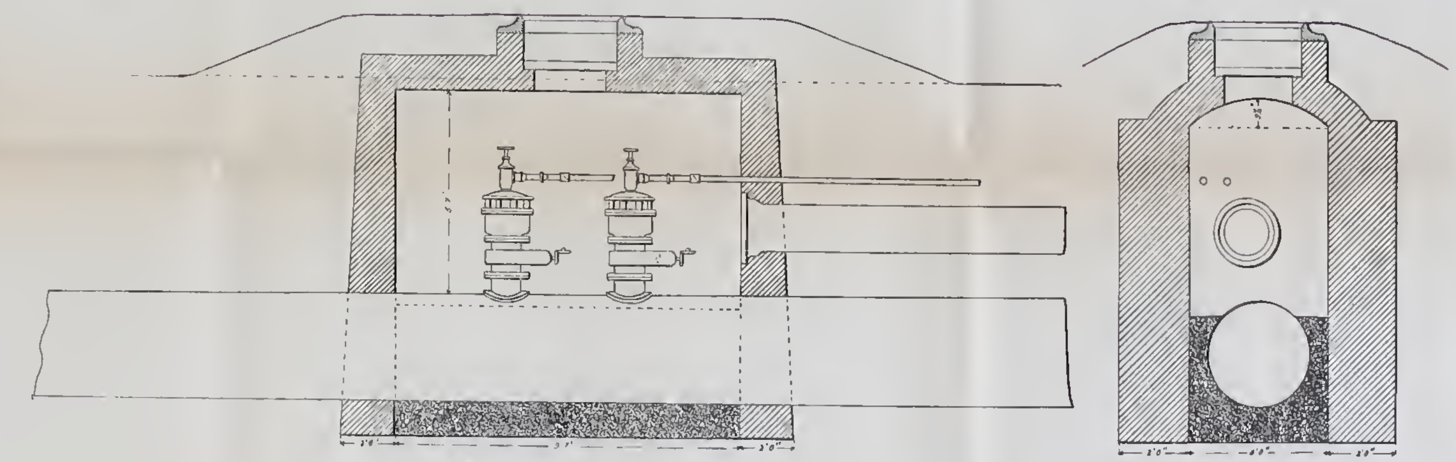
SCALE FOR FIGS. 1 TO 6



SIDE ELEVATION
FIG. 3

UP-STREAM ELEVATION OF BLOW-OFF GATE
FIG. 4

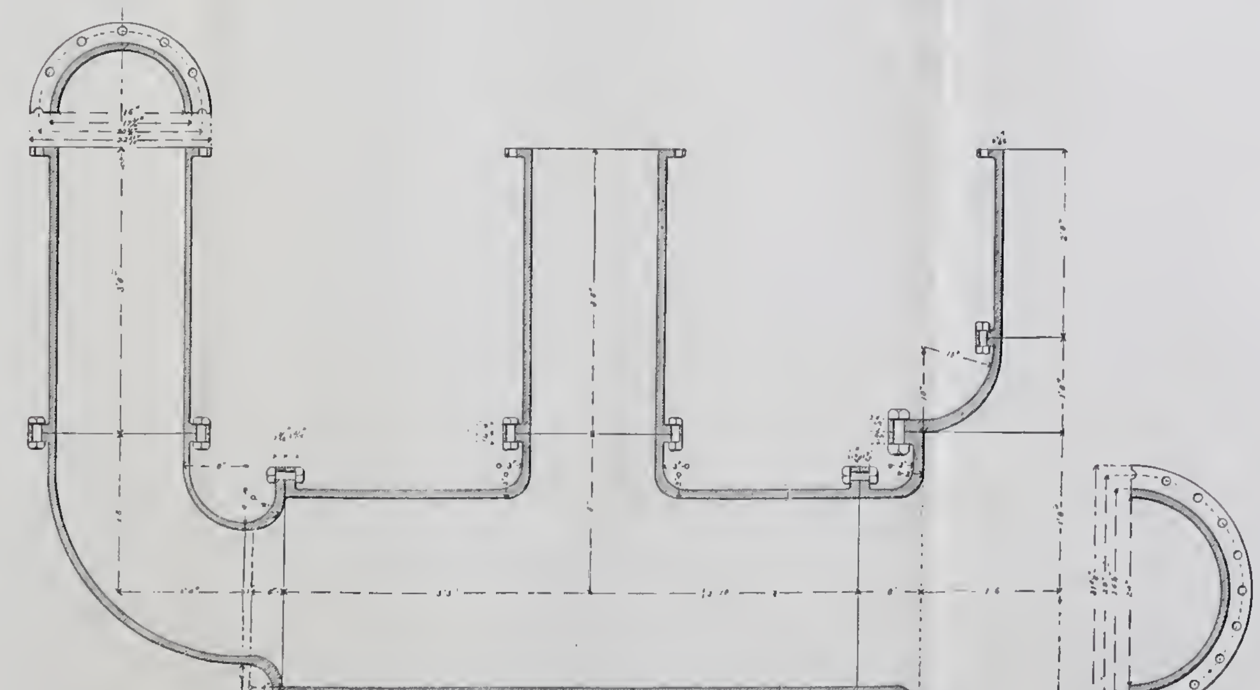
DETAILS OF INTERLOCKING BLOW-OFF APPARATUS



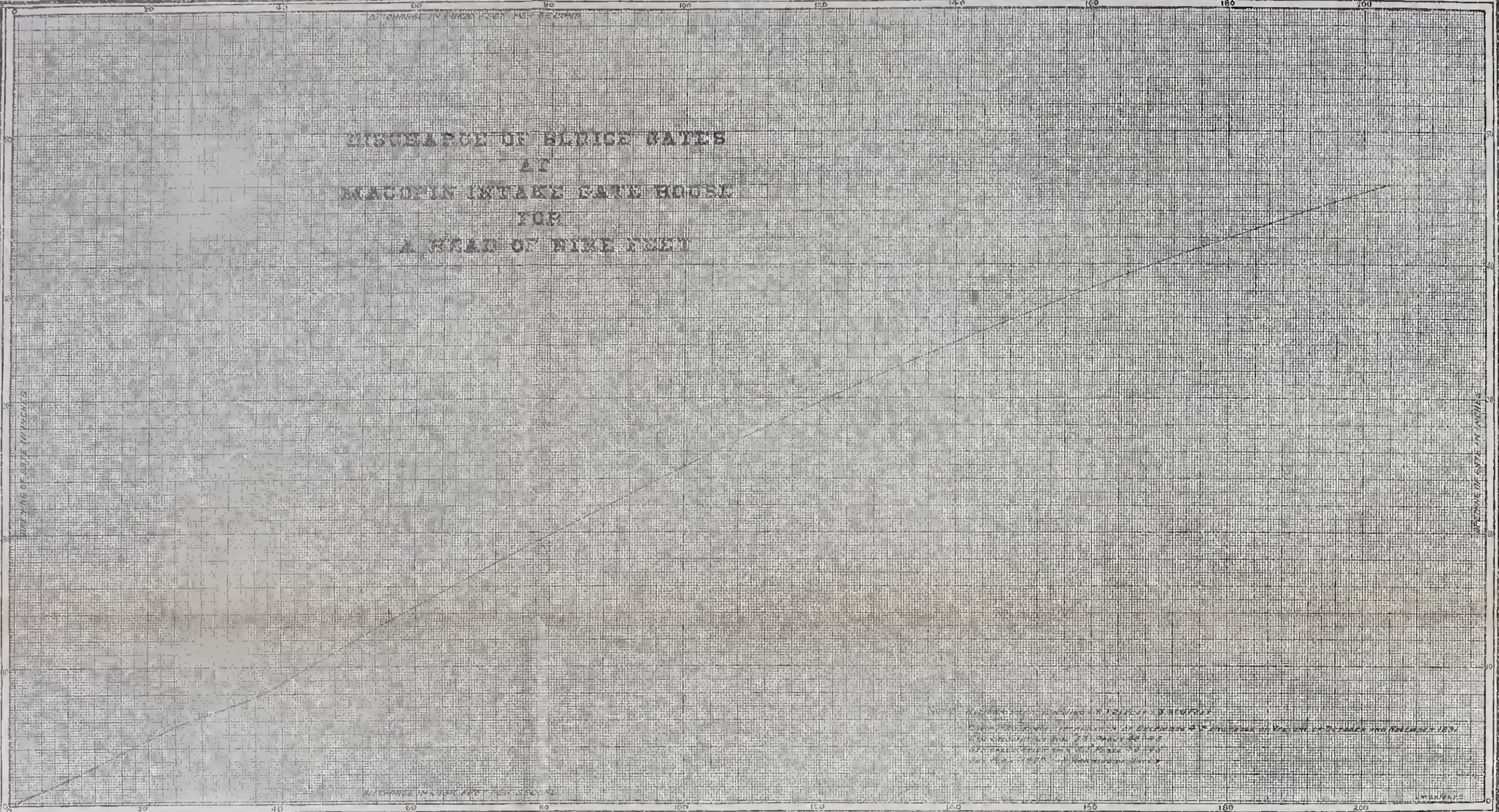
LONGITUDINAL SECTION

CROSS SECTION

AIR VALVE VAULT



MANIFOLD CONNECTION

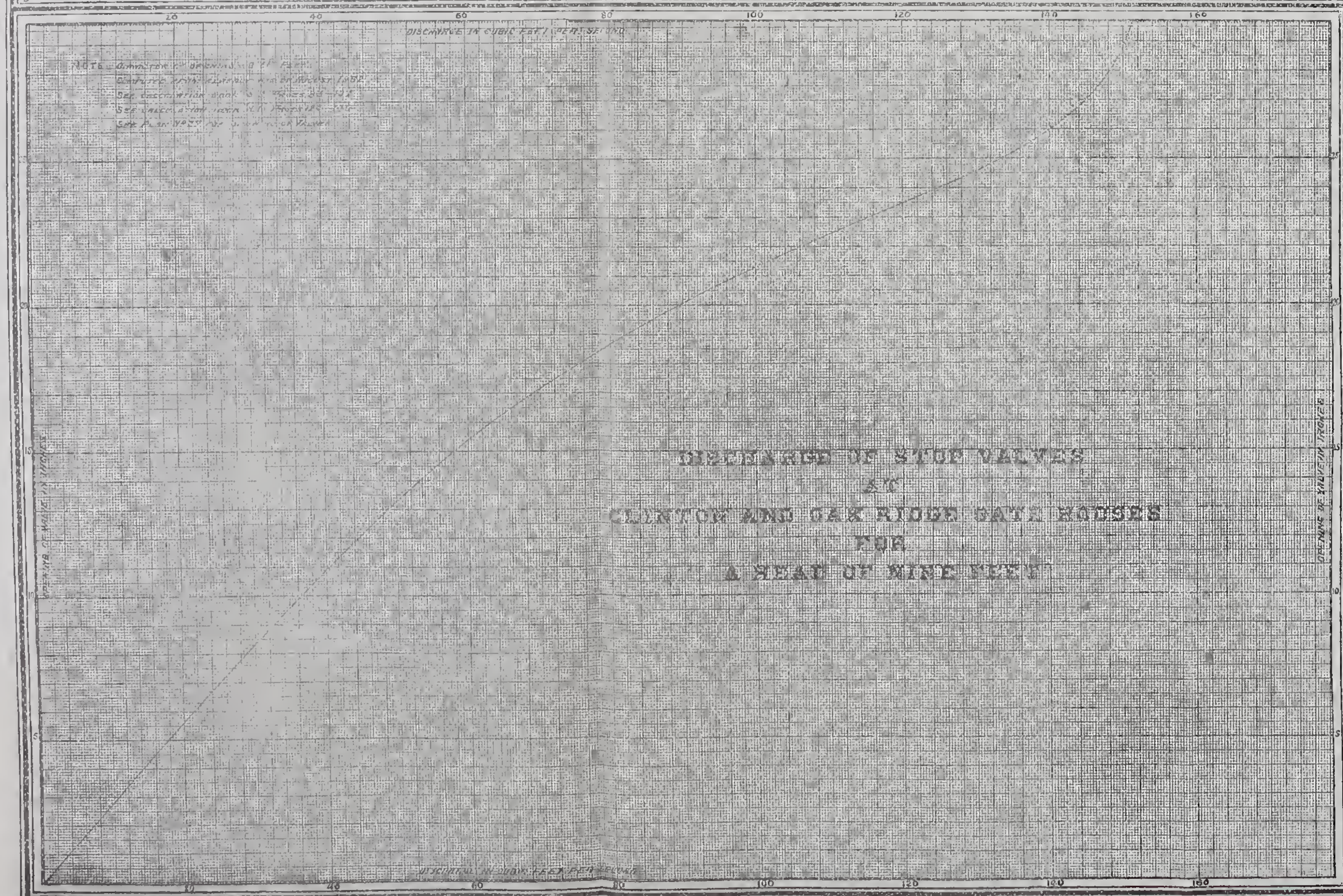


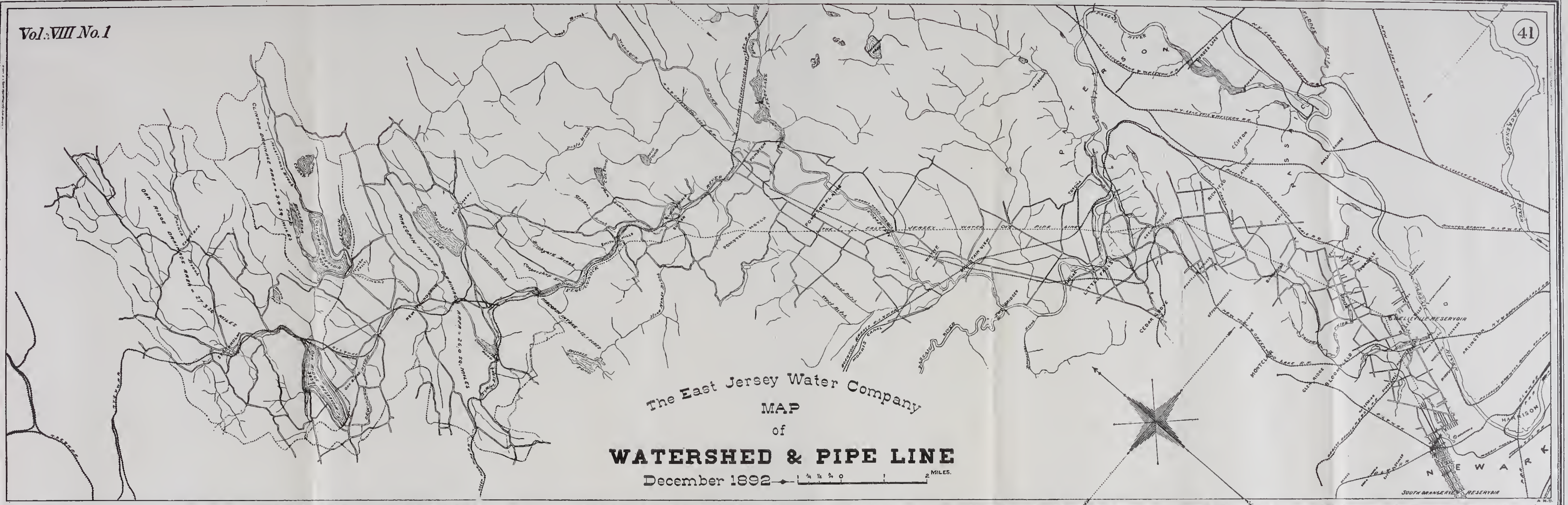
THE

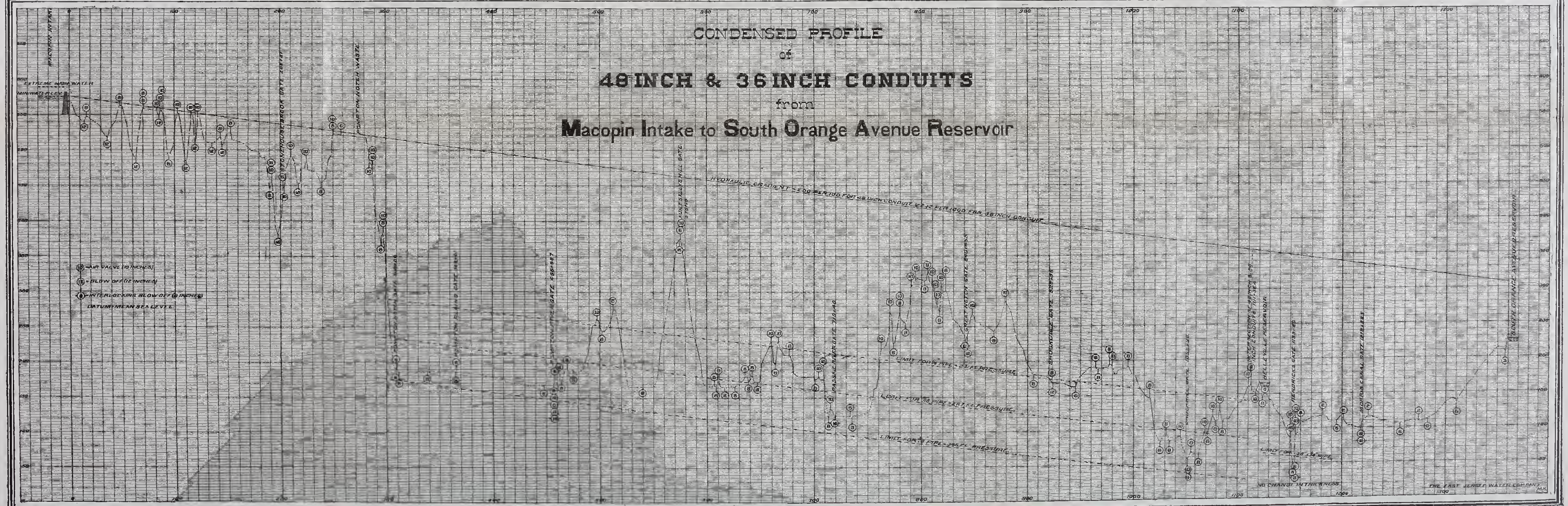
EAST JERSEY WATER COMPANY

DISCHARGE DIAGRAMS

DECEMBER 1892




The East Jersey Water Company
MAP
of
WATERSHED & PIPE LINE
December 1892
MILES.
BELLEVILLE RESERVOIR
NEWARK
HARRISON
SOUTH ORANGE AVE. RESERVOIR


CONDENSED PROFILE
of
48 INCH & 36 INCH CONDUITS
from
Macopin Intake to South Orange Avenue Reservoir
HYDRAULIC GRADIENT
DATUM MEAN SEA LEVEL
NO CHANGE IN THICKNESS
THE EAST JERSEY WATER COMPANY

Flow of Pequannock River, etc. — Continued.

	All Quantities in Million Gallons.											
	Flow of River per Drainage Area.			Total Natural Flow of River.	Taken from or added to Oak Ridge.	Volume in Oak Ridge.	Taken from or added to Clinton.	Volume in Clinton.	Waste from each Drainage Area.			
	Macopin.	Oak Ridge.	Clinton.						Macopin.	Oak Ridge.	Clinton.	Total Waste.
Nov. 30 to Dec. 6	356	307	143	806	+ 307	1,649	+ 143	1,261	6	. .	. .	6
Dec. 7 to 13 . .	279	259	169	707	+ 188	1,837	+ 169	1,430				
14 to 20 . .	153	123	296	472	. . . .	"	+ 122	1,552				
21 to 27 . .	382	437	222	1,041	+ 437	2,274	+ 222	1,774	32	. .	. .	32
28 to Jan. 3	873	755	238	1,866	+ 284	2,558	+ 238	2,012	523	471	. .	994
1892.												
Jan. 4 to 10 . .	469	439	263	1,171	. . . .	2,558	+ 263	2,275	119	439	. .	558
11 to 17 . .	868	868	287	2,023	. . . .	"	+ 287	2,562	518	868	. .	1,386
18 to 24 . .	782	783	248	1,813	. . . .	"	+ 248	2,810	432	783	. .	1,215
25 to 31 . .	333	333	111	777	. . . .	"	+ 111	2,921	. .	316	. .	316
Feb. 1 to 7 . .	226	226	65	517	. . . .	"	+ 65	2,986	. .	102	. .	102
8 to 14 . .	199	200	48	447	. . . .	"	+ 48	3,034	. .	49	. .	49
15 to 21 . .	138	139	47	324	− 73	2,485	+ 47	3,081				
22 to 28 . .	202	203	56	461	+ 55	2,540	+ 56	3,137				
29 to Mar. 6	156	156	87	399	− 38	2,502	+ 87	3,224				
Mar. 7 to 13 . .	361	361	102	824	+ 56	2,558	+ 102	3,326	11	305	. .	316
14 to 20 . .	232	233	98	563	. . . .	"	+ 98	3,424	. .	115	. .	115
21 to 27 . .	288	288	104	680	. . . .	"	+ 104	3,528	. .	226	. .	226
28 to April 3	340	341	100	781	. . . .	"	+ 11	3,539	. .	331	89	420
April 4 to 10 . .	246	247	83	576	. . . .	"	. . . .	"	. .	143	83	226
11 to 17 . .	160	160	80	400	. . . .	"	. . . .	"	. .	. .	50	50
18 to 24 . .	182	182	80	444	. . . .	"	. . . .	"	. .	14	80	94
25 to May 1	58	58	80	196	− 154	2,404	. . . .	"				
May 2 to 8 . .	115	115	80	310	− 40	2,364	. . . .	"				
9 to 15 . .	125	126	80	331	− 19	2,345	. . . .	"				
16 to 22 . .	329	196	83	608	+ 115	2,520	. . . .	"	. .	. .	83	83
23 to 29 . .	377	364	114	855	+ 38	2,558	. . . .	"	27	326	114	467
30 to June 5	523	258	156	937	. . . .	"	. . . .	"	173	258	156	587
June 6 to 12 . .	354	508	131	993	. . . .	"	. . . .	"	4	508	131	643

Flow of Pequannock River, etc. — Continued.

	All Quantities in Million Gallons.											
	Flow of River per Drainage Area.			Total Natural Flow of River.	Taken from or added to Oak Ridge.	Volume in Oak Ridge.	Taken from or added to Clinton.	Volume in Clinton.	Waste from each Drainage Area.			
	Macopin.	Oak Ridge.	Clinton.						Macopin.	Oak Ridge.	Clinton.	Total Waste.
June 13 to 19 . .	145	155	53	353	. . . .	2,558	. . . .	3,539	. .	3	. .	3
20 to 26 . .	165	182	65	412	. . . .	"	. . . .	"	. .	62	. .	62
27 to July 3	139	151	50	340	. . . .	"	— 10	3,529				
July 4 to 10 . .	73	79	26	178	. . . .	"	— 172	3,357				
11 to 17 . .	44	47	17	108	. . . .	"	— 242	3,115				
18 to 24 . .	28	30	10	68	. . . .	"	— 282	2,833				
25 to 31 . .	34	38	14	86	. . . .	"	— 264	2,569				
Aug. 1 to 7 . .	45	48	16	109	. . . .	"	— 241	2,328				
8 to 14 . .	72	77	26	175	. . . .	"	— 175	2,153				
15 to 21 . .	21	26	9	56	. . . .	"	— 294	1,859				
22 to 28 . .	72	82	26	180	. . . .	"	— 170	1,689				
29 to Sept. 4	106	35	23	164	. . . .	"	— 186	1,503				
Sept. 5 to 11 . .	36	26	10	72	. . . .	"	— 278	1,225				
12 to 18 . .	98	105	37	240	. . . .	"	— 110	1,115				
19 to 25 . .	37	42	15	94	. . . .	"	— 256	859				
26 to Oct. 2	12	14	12	38	. . . .	"	— 312	547				
Oct. 3 to 9 . .	17	21	8	46	. . . .	"	— 304	243				
10 to 16 . .	14	16	5	35	— 90	2,468	— 225	18				
17 to 23 . .	16	19	2	37	— 313	2,155	. . . .	"				
24 to 30 . .	16	18	2	36	— 314	1,841	. . . .	"				
31 to Nov. 6	80	23	3	106	— 247	1,594	+ 3	21				
Nov. 7 to 13 . .	80	81	16	177	— 189	1,405	+ 16	37				
14 to 20 . .	419	434	154	1,007	+ 434	1,839	+ 154	191	69	. .	. .	69
21 to 27 . .	133	135	78	346	— 82	1,757	+ 78	269				
28 to Dec. 4	98	105	51	254	— 147	1,610	+ 51	320				
Dec. 5 to 11 . .	218	306	108	632	+ 174	1,784	+ 108	428				
12 to 18 . .	185	207	86	478	+ 42	1,826	+ 86	514				
19 to 25 . .	93	98	49	240	— 159	1,667	+ 49	563				
26 to Jan. 1	122	131	51	304	— 97	1,570	+ 51	614				

Flow of Pequannock River, etc. — Concluded.

	All Quantities in Million Gallons.											
	Flow of River per Drainage Area.			Total Natural Flow of River.	Taken from or added to Oak Ridge.	Volume in Oak Ridge.	Taken from or added to Clinton.	Volume in Clinton.	Waste from each Drainage Area.			
	Macopin.	Oak Ridge.	Clinton.						Macopin.	Oak Ridge.	Clinton.	Total Waste.
1893.												
Jan. 2 to 8 . .	381	413	160	954	+ 413	1,983	+ 160	774	31	. .	. .	31
9 to 15 . .	168	182	75	425	0	"	+ 75	849				
16 to 22 . .	88	94	45	227	— 168	1,815	+ 45	894				
23 to 29 . .	120	130	36	286	— 100	1,715	+ 36	930				
30 to Feb. 5	170	184	58	412	+ 4	1,719	+ 58	988				
Feb. 6 to 12 . .	560	599	160	1,319	+ 599	2,318	+ 160	1,148	210	. .	. .	210
13 to 19 . .	508	546	203	1,257	+ 240	2,558	+ 203	1,351	158	306	. .	464
20 to 26 . .	473	508	115	1,096	0	"	+ 115	1,466	123	508	. .	631
27 to Mar. 5	232	251	75	558	0	"	+ 75	1,541	. .	133	. .	133
Mar. 6 to 12 . .	727	788	204	1,719	0	"	+ 204	1,745	377	788	. .	1,165
13 to 19 . .	1,115	1,195	454	2,764	0	"	+ 454	2,199	765	1195	. .	1,960
20 to 26 . .	650	705	258	1,613	0	"	+ 258	2,457	300	705	. .	1,005
27 to April 2	576	624	288	1,488	0	"	+ 288	2,745	226	624	. .	850
April 3 to 9 . .	452	490	248	1,190	0	"	+ 248	2,993	102	490	. .	592
10 to 16 . .	391	424	170	985	0	"	+ 170	3,163	41	424	. .	465
17 to 23 . .	491	532	225	1,248	0	"	+ 225	3,388	141	532	. .	673
24 to 30 . .	362	389	130	881	0	"	+ 130	3,518	12	389	0	401
May 1 to 7 . .	1,118	1,200	409	2,727	0	"	+ 21	3,539	768	1200	388	2,356
8 to 14 . .	472	506	173	1,151	0	"	0	"	122	506	173	801
15 to 21 . .	400	429	146	975	0	"	0	"	50	429	146	625
22 to 28 . .	191	206	70	467	0	"	0	"	0	47	70	117

THE LOCATION. CONSTRUCTION AND LAYING OF THE 54-INCH STEEL SUBMERGED PIPE IN SKANEATELES LAKE FOR THE SYRACUSE WATER WORKS.

BY

William R. Hill, Chief Engineer Syracuse Water Works, Syracuse, N. Y.

Read June 15th, 1893.

In the year of 1889 the Syracuse Water Commission, after a thorough investigation of the various proposed sources, recommended Skaneateles Lake as offering the best water supply available.

Skaneateles Lake is a beautiful sheet of water, located about 20 miles southwesterly from Syracuse. This lake is about 16 miles long, by about three-quarters of a mile wide, having an area of 12.75 square miles and a tributary water shed, exclusive of lake, of 60.28 square miles.

In elevation, the high water line is 867.096 feet above the mean low tide at Albany, New York, 466.40 feet above the level of Syracuse, and 246.40 feet above the flow line of the Distributing Reservoir now being constructed.

The water is taken from the northerly end of the lake by means of a 54-inch steel pipe, extending from the Intake Crib to the Gate House, from which the water is carried by gravity through a 30-inch cast iron pipe, to the Distributing Reservoir in the city of Syracuse.

THE LOCATION.

It has been observed, after a strong southerly wind, that the water in the northerly end of the lake, where it is less than 20 feet in depth, was roiled for a distance of about 4000 feet back from the foot of the lake. Taking this fact into consideration, it was necessary to reach the clear water beyond in as direct a line as possible.

In order to determine upon the location of the submerged pipe line, a hydrographical survey was made, extending from the foot of the lake southerly, for about one and one-half miles. The location of the lake shore and of the base line on the west side, together with taking about 3000 individual soundings, were included in this survey.

In making the soundings, a small steam yacht containing the sounding party of four men, was used. The soundings were taken on parallel lines, extending across the lake from successive 100 foot stations of the base line. Before taking a line of soundings a transitman would set his instrument over the proper station of the base line and give line for anchoring in range on the line of sounding, two buoys, which served as guides for keeping the boat on line.

Beginning at the east shore of the lake and opposite the station of the base line, over which the transit was set, the boat was started on line and soundings taken about 100 feet apart. As each sounding was made, the whistle was blown and the transitman at the station on base line, took an angle on the whistle, as did also a second transitman, who was permanently located at the foot of the lake and in such position, that the line of sight of his instrument would intersect the line on which the soundings were taken, at nearly right angles.

The soundings were measured by means of a steel tape to which was attached a sounding iron, weighing about four pounds. The sounding iron had a concave base which was filled with soap, thus affording a means of obtaining a sample of the material forming the lake bottom. As soon as a sounding was made the recorder, on board the boat, entered in his book the number, the depth and the time. The two transitmen on the shore also recorded the number of the sounding, the angle and the time. From these notes, the three thousand soundings were easily plotted and an accurate contour map of the lake bottom was made, from which the final location of the pipe line was determined.

The contour map of the lake shows the Intake Crib located in 38 feet of water and 6410 from the Gate House on the shore, at the north end of the lake.

Three separate analyses of water taken at the surface directly over the Crib, halfway down, and at the Crib respectively, show the water at the Crib to be the purest, the surface water next, while the sample taken halfway down, ranked third in quality.

THE CONSTRUCTION.

This work consisted of about 6400 linear feet of single riveted steel pipe, having an internal diameter of 54 inches.

This pipe was made by the Groton Bridge and Manufacturing company, of Groton, N. Y., from $\frac{3}{8}$-inch steel plates, weighing 15 pounds per square foot and rolled at the mills of Carnegie, Phipps and Company, at Homestead, Pa.

The plates were each 6 feet wide, and of such length as would form the proper circle of the pipe and the necessary lap of $2\frac{1}{2}$ inches. Five of these 6-foot sections were then telescope joined and riveted to form a rigid section 29 feet 2 inches in length. The edges of the longitudinal seams and of the circular joints, both outside and inside, were beveled and hammer calked until they were made water tight, without plugging or packing, the same as is usually done on first-class boiler work.

These 29 foot sections after being tested and coated with asphalt, were shipped to the delivery grounds on the shore of Skaneateles Lake, where four of these sections were joined and riveted together forming a rigid section about 116 feet in length. On one end of this long section, (Fig. 1)* a spigot of $2\frac{5}{8}$x$\frac{3}{4}$-inch steel, (C) was riveted, while on the opposite end there was a

*Cuts loaned by "Engineering News."

DETAILS

OF

54-INCH STEEL PIPE JOINTS,

Syracuse Water Works,

WILLIAM R. HILL, Chief Engineer.

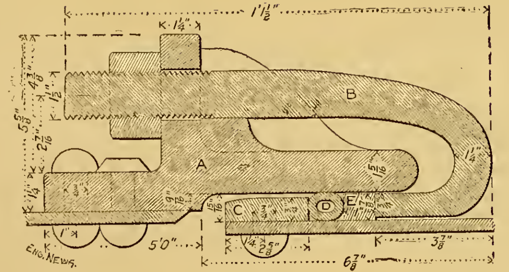


FIG. 1.

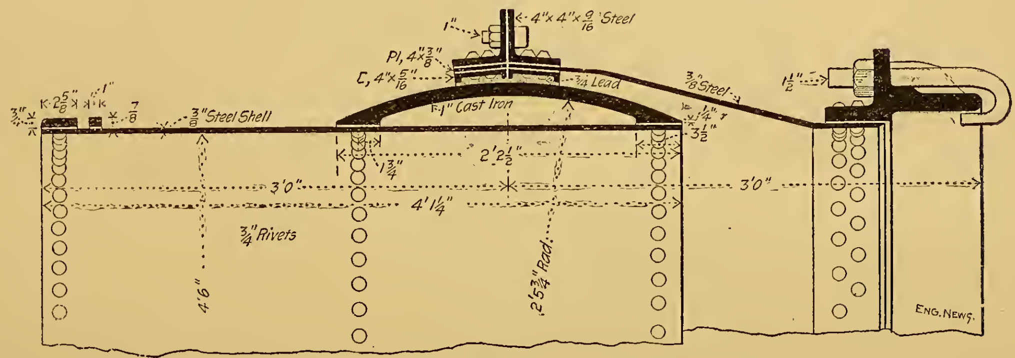


FIG. 2.

cast-iron bell, (A.) On the spigot end there was a 1x$\frac{7}{8}$-inch wrought iron hoop loosely encircling the pipe, and between this hoop (E) and the steel spigot was placed a soft lead pipe, (D.)

The cast iron bell was provided with twenty steel hook bolts (B) with hexagonal nuts. After entering the spigot into the bell, the hook bolts were brought to bear against the wrought iron hoop which in turn pressed against the soft lead pipe causing it to upset and form a cold lead joint.

There were used on this line, seven universal flexible joints, (Fig. 2)* made from steel plates, channels and angles, on the ball and socket principle, consisting of a turned cast iron hollow zone or ball, working in a spherical lead lined steel socket and capable of a deflection of 12 degrees, in any direction, from the axis of the pipe.

The plates were of mild steel of an ultimate tensile strength of from 55,000 to 65,000 pounds per square inch.

All plates were required to be able to stand the test of punching a row of holes $\frac{3}{4}$-inch in diameter, pitched $1\frac{1}{4}$ inches between centres, without causing cracks; and to withstand the test of enlarging to the extent of one-third their original diameters, a row of punched rivet holes, centre pitched two diameters from the edge of the plate and three diameters apart, without cracking the sheets.

Strips cut from the sheets lengthwise and crosswise, were required to stand the test of cold bending double, flat under the hammer, without fracture. The plates had to be tough and pliable enough to allow of cold scarfing to a fine edge at the laps, without cracking and to be rolled to the circle of the pipe, without cracking between the rivet holes and the edge of the plate.

The plates were shipped from the rolling mills to Groton on flat cars provided with roofs to protect the steel from rain. After being unloaded, the plates were laid out and hand-pricked for punching from carefully made templets; they were then passed to the punch and then to the chamfering machine where both the side edges of each plate were cut to curves, so that in bending the plate to the circle of the pipe, the ends of the 6 foot telescope section thus formed would be at right angles to the axis of the pipe and have an internal diameter of 54 inches aud $54\frac{3}{4}$ inches respectively. The edges of the plates at the lap were next beveled to a fine edge by hammering and were then passed to the rolls which were so arranged that the plate was formed to the proper circle. As soon as they were thus formed, they were temporarily held in shape by bolts and were then assembled for riveting.

At this part of the shop, there were two parallel hand car tracks, just far enough apart to allow men to work handily between the two cars on which the pipe sections were placed. Over these tracks was suspended an Allen pneumatic riveter.

As soon as the rivets were driven on the pipe section on track No. 1, the riveter was swung over track No. 2, where in the meantime another section had been put in position by the assemblers. Then while the riveter was

*Cuts loaned by "Engineering News."

working over track No. 2, the assemblers placed another section in position on track No. 1. This rotation was kept up until five 6-foot sections had been riveted together, making a 29-foot section. These long sections were then placed on skids in another part of the shops, where the seams were calked with a pneumatic tool and the pipes thoroughly cleaned from all scales or dirt. They were then inspected and taken to the dipping tank to receive the asphalt coating.

The dipping tank was made of ¼-inch steel plates and was 31 feet long by 5 feet 6 inches wide by 5 feet 6 inches deep, having the bottom rounded and fitted with rolls to allow the pipe to be revolved in the bath. Extending underneath and supporting this tank, was a brick furnace fitted with an ordinary grate for burning wood. The coating was a mixture of the Los Angeles Oil Burning Supply Company's dry asphalt, Grade D, and their liquid asphalt Grade G. To start a dip, it was necessary to use three parts of D to one part of G; but once started it was necessary to add the Grade G only. The temperature of the mixture was tested by immersing in the boiling mass a piece of ⅜-inch steel plate about six inches square, which was allowed to remain therein about ten minutes, when it was removed and immediately cooled in ice cold water. If the coating did not then crack or fly off upon striking the plate with a hammer and did not soften at a temperature of 100 degrees Fahr. it was considered to be of the proper temper.

The pipe was then completely submerged in the bath, and left therein at least 20 minutes, or long enough for the steel to attain the temperature, not less than 280 degrees Fahr., of the mixture. It was then withdrawn, and the coating allowed to stiffen for a few moments, and then again immersed a short time to thicken the coat.

The pipes were raised and lowered into the bath by means of a derrick. It required about 45 minutes to properly coat one of the 29-foot sections.

THE LAYING.

The contract for laying the submerged pipe, was awarded to Messrs. Hingston & Chapman, of Buffalo, N. Y. Before laying any pipe they constructed a catamaran 95 feet long, 30 feet wide and 6 feet deep. This was made in two sections, each 95 feet long and 12 feet wide. The sides and ends of each section were formed entirely of 6"x12" oak timbers placed on top of each other and secured by bolts. These two sections were placed side by side and 6 feet apart and held in this position by five 12"x14" oak timbers. Each section was covered by a plank floor, but the 6-foot space, between the two sections, was left open.

Over this opening were arranged three timber supports for the pulley blocks from which a length of pipe could be suspended.

The Intake Crib, 16 feet square and 12 feet deep, was constructed of 10"x12" oak timbers, dovetailed and secured by 1¼ inch rods. This crib containing a short bell mouth section of the intake pipe, having a flexible joint attached to its outer end, was built on board the catamaran, and after being carried out near where it was to be anchored, it was launched and floated in position

between four guide piles. Stone ballast was then added until the Crib sunk upon the broken stone foundation, which had already been prepared. After the Crib had been placed, a section of the steel pipe, the ends of which had been closed by oiled canvas, was rolled off the skids into the water and floated out to the catamaran which was held in position by spud piles over where the pipe was to be lowered. The pipe was then drawn into the open space between the two sections of the catamaran where the timber saddle pieces were fastened to the pipes and the ropes and tackling adjusted.

Upon removing the oil canvas bulkheads, the pipe filled with water and supported by the ropes, it was lowered into position on the lake bottom. Before the ropes were removed, the divers entered the spigot into the bell, adjusted the hook bolts and by screwing up the nuts, upset the lead pipe and formed the joint.

The booms from which the pipe was suspended, were so constructed that the pipe could also be moved longitudinally. As the catamaran was made so large and of such heavy timbers there was no trouble experienced from unsteadiness, except when the water was very rough; however under ordinary conditions, the contractors were able to lay one of the 116-foot sections in one day.

The total cost of the steel pipe, including the flexible joints, delivered on the skids at Skaneateles Lake, was $8.80 per linear foot and the contract price for laying the same was $2.50 per linear foot.

Owing to the trench not being dredged, the pipe laying was suspended last fall and there still remains about 2000 feet of the pipe to be laid in the Lake. This dredging is now nearly finished and the pipe laying will be resumed about the first of July.

All of the 30-inch cast-iron pipe for the conduit line from the Lake to Syracuse, will be delivered by August 15th, and pipe laying is now in progress on all four sections of this line. The work on the new Distributing Reservoir is also well under way but will not be completed until the fall of 1894.

It is expected, however, to have Skaneateles Lake water into the present Reservoir before the end of the current year.

THE PURIFICATION OF WATER BY FREEZING.

BY

Thomas M. Drown, Professor of Analytical Chemistry, Massachusetts Institute of Technology, Boston.

[Read June 15, 1893.]

The rapid growth of the artificial ice industry, and the claim frequently made that artificial ice is much purer than natural ice, makes it desirable that the relation between the quality of ice, and the quality of water from which it is formed, should be fully understood.

Freezing of water is ordinarily a process of purification, that is to say, the ice is usually purer than the water which is frozen. And yet, under certain conditions of freezing, the ice may contain the impurities of water in a highly concentrated condition.

The purification of water by freezing can be best observed in nature, when ice is formed slowly on deep ponds in winter. Laboratory experiments on the freezing of water containing known amounts of various substances in solution, are generally less satisfactory because the abstraction of the heat of the water by freezing mixtures is usually very rapid, and also because the amount of water experimented with is comparatively small.

In the formation of ice on deep ponds in winter, it is the surface only that is affected, and the rate of freezing decreases as the ice increases in thickness. The water freezes very slowly after the ice is a few inches or more in thickness, and it is under these conditions that the greatest purification—that is to say, the most perfect elimination of the substances in solution in the water—takes place.

The State Board of Health, of Massachusetts made, a few years ago, a very thorough investigation of the ice supplies of the State,* and many interesting facts with regard to the purification of water by freezing were then determined.

A sample of ice from an unpolluted pond was found to be purer than most distilled water, it had no color, no free or albuminoid ammonia or nitrites, and contained only 0.2 part of mineral matter per 100,000 [equal to 0.1 grain per gallon] and .0050 part of nitrogen as nitrates. This ice was formed from water which had 3.15 parts of mineral matter, .0192 part of albuminoid ammonia, 0.44 part of chlorine, and 0.0100 part of nitrates. Among the 275 analyses of ice and water made in the course of this investigation, there were many instances where the degree of purification was as great as the one cited. In as many cases as possible the comparison of the

*Twenty-first Annual Report pp. 143-223.

water and ice was made by cutting out a piece of ice from the pond and then taking a sample of water from the opening made in the ice. Where ice harvesting was in progress corresponding samples of water and ice were easily obtained. The following table contains the average composition of ten samples of water and the corresponding ten samples of ice. In each case the water and ice were collected at the same time, as above described. Some of the ponds and rivers included in these averages were unpolluted, but the majority of them contained considerable sewage or the drainage of houses or stables. The determinations were made on the melted ice after filtering through paper.*

COMPARISON OF TEN BODIES OF WATER AND THE CORRESPONDING ICE.

Parts per 100,000.

	Color.	Fixed residue.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.
Water...	0.3	6.075	.00864	.01350	.617	.0430	.00060
Ice................	0.0	.391	.00112	.00108	.010	.00430	.00003
Percentage remaining in Ice.	0.	6.4	13.	8.	1.6	10.	.5

In the above cases the comparison is made between the water and the whole mass of ice. A comparison between the water and the bottom portion of the ice would generally show a still higher purification. It is not at all uncommon in the bottom ice to find free and albuminoid ammonia and chlorine entirely absent. This is not often the case in the top ice, and snow ice is generally quite impure.

The progressive improvement in the quality of the ice from the top downwards is well shown in the following analysis of a block of ice which was divided into five layers.

*It is important that the ice be melted without contact with the air of the laboratory. This may be accomplished by putting fragments of ice, after washing with distilled water, into a wide-necked bottle, and allowing the ice to melt after closing the bottle with a glass stopper. The fragments of ice must not be touched with the hands.

Analysis of Ice in Five Layers.

Thickness of Ice 9 Inches.

Parts per 100,000.

	Fixed Residue.	Free Ammonia.	Albumin. Ammonia. In Solution.	Albumin. Ammonia. In Suspension.	Chlorine.
Top layer with snow ice........	1.10	.0080	.0048	.0166	.02
Second layer....................	0.50	.0034	.0012	.0056	.02
Third layer......................	0.55	.0016	.0008	.0032	.01
Fourth layer............	—	.0016	.0008	.0022	.00
Fifth layer......................	0.05	.0012	.0002	.0006	.00

We may fairly conclude from the above that the degree of purification in freezing is dependent on the rate, the slower the process the more complete the elimination of the dissolved and suspended matter in the water.

From this series it is also apparent that there is a progressive improvement in the ice as it increases in thickness as regards the *suspended* impurities. When the ice is forming quickly the suspended matter in the water is probably entangled to a greater or less extent in the ice crystals. In a case in which a body of sewage was frozen to a depth of one inch, the ice contained only five per cent. of the dissolved organic matter [as indicated by the albuminoid ammonia], while it had 28 per cent. of that which was in suspension.

As regards the bacteria there is also progressive improvement in the quality of the ice from above downwards as might be expected from the above results. The bacteria determinations made in connection with the chemical analyses in these investigations showed that the snow ice contained as many as 81 per cent. of the bacteria of the water, and the clear, bottom ice only two per cent. This large removal of bacteria may, of course, be partly due to their destruction by long continued cold, but the researches of Dr. Prudden, Dr. Billings, and others have shown that many specific bacteria resist the action of cold for a very long time.

The greater impurity of the top ice may be due to various causes. The ice first formed on a surface of water more or less ruffled by the wind will enclose, doubtless, more of the impurities of the water than when freezing goes on more slowly and quietly. Again, the surface of the ice may be flooded by

the water from below; this is often intentionally done by ice cutters. When this water is frozen solid there is, of course, no opportunity for the elimination of dissolved matter. Further, the dust and dirt of various kinds which fall upon the ice, especially on ponds near cities, the impurities which snow brings down out of the atmosphere, and the contamination of the surface by men and horses at the time of ice cutting, all tend to render the surface ice impure.

If a block of ice from a pond near a city or railroad, with snow, or very porous ice on the top, is divided, and the upper and lower portions allowed to melt separately, in clear white glass bottles, the difference in their character is very strikingly shown. The water from the surface deposits generally a very considerable amount of sediment, the greatest part of which is black, looking like soot or cinders, while the bottom portion is often free from turbidity and sediment. When snow, which has fallen in cities is melted, the water is very dirty, and smells strongly of soot.

The elimination of the impurities of water when it freezes, is necessarily accompanied by a concentration of the impurities in the water itself. Ordinarily in a pond of considerable depth, this concentration would be relatively so slight that it would not be noticed. In two cases, however, where I examined samples of water immediately under the ice, they had a deeper color and more organic matter than the water taken at greater depths, showing, apparently, that the organic matter which had been expelled from the water by slow and undisturbed freezing had accumulated under the ice and had not yet mixed with the great mass of water in the pond.

When a shallow pond freezes to the bottom, it is evident that the ice last formed must contain the greater part of the impurities of the whole body of water. So great is the tendency to purification in freezing that it is in the lower few inches of ice that one must expect to find the greater part of the impurities in cases where the whole body of water is frozen solid.

A not uncommon practice in places where there are no natural ponds, is to flood low ground before cold weather comes on in order to gather an ice crop. When such a shallow pond freezes solid, the organic matter which the water has soaked out of the ground must be in a highly concentrated state in the bottom ice.

It is not improbable in some of the cases in which ice has been known to be the cause of sickness that it was cut from shallow ponds with dirty bottoms. The well known epidemic at Rye Beach, N. H., in 1875, is a case in point. The ice which caused the trouble was cut from a flooded marsh, the water being only two feet deep and containing a good deal of sawdust.

In the ordinary process of making artificial ice the whole mass of water is frozen, and consequently if the water used is not pure we must expect a concentration of the impurities in the portion last frozen. Large cans of galvanized iron, of a capacity of 200 to 250 pounds of water are filled with water and exposed on the outside to a circulating solution of brine which is cooled below the freezing point of water. About two days are required to freeze this

quantity of water to a solid block. The ice first forms on the sides of the can and gradually increases in thickness until the whole mass is solid.

I have recently made some analyses of blocks thus frozen, to determine the distribution of the mineral and organic matter The blocks were divided into six portions, namely, an upper, middle and lower portion of the outside, and an upper, middle and lower portion of the interior core. It was found in all cases that the lower portion of the core of the block contained the greater portion of the impurities of the water. One would naturally suppose that the middle and upper portion of the core would contain the greatest amount of the impurities (as is the case of the segregation of the impurities in the cooling of a steel ingot), but there were some conditions of cooling in the cakes of the ice blocks which determined the portion near the bottom to be the last frozen.

The most interesting case of this segregation was noticed in the freezing of a well water which contained a considerable amount of mineral matter in solution. On page 51 are the analyses of the water used and of the different portions of the ice cake:

These analyses are very interesting and instructive. In this one block of ice, weighing 200 pounds, are portions of high purity, and other portions which contain an amount of mineral matter greater than is desirable in a good drinking water. It is not improbable that the ice from the lower portion of the core would produce intestinal disturbance in those accustomed to soft water. Not only was the mineral matter concentrated in the portion last frozen, but the small amount of organic matter in the original water was also found here.

One might be sorely puzzled to interpret the analysis of this concentrated portion of the ice block, if he did not know its origin. Judged as a sample of water the explanation might well be that it was a tolerably well purified effluent of highly concentrated sewage!

Another interesting fact with regard to this portion of the ice was that on being melted, the water contained a large amount of white suspended matter, which on analysis proved to be silica.

Samples of ice made from distilled water were also examined. The amount of dissolved matter in distilled water is extremely small, yet the process of concentration is, even in such cases, generally noticeable. Thus in one instance where distilled water was frozen the chlorine was increased from .02 part per 100,000 in the water to .33 part in one portion of the ice.

It is interesting in this connection to mention that a sample of distilled water taken from the rubber hose used to fill the cans had a slight odor of rubber. This odor was distinctly perceived in the lower portion of the ice block (when melted), but was not noticed in any other portions of the ice.

From the above we may conclude that the claim for purification by freezing can only be admitted when a mass of water is partially converted into ice. When a body of water is completely frozen, whether in a pond or in a can, the ice as a whole has the same composition as the water itself. Under these

Well Water, Boiled and Filtered, Used for Freezing.

	Appearance.			Odor.		Total Residue on Evaporation.	Ammonia.		Chlorine.	Nitrogen as		Hardness.	Oxygen Consumed.
	Turbidity.	Sediment.	Color.	Cold.	Hot.		Free.	Albuminoid.		Nitrates.	Nitrites.		
	None.	None.	0.00	None.	None.	18.04	.0110	.0010	3.45	.7500	.0200	4.4	.0547
	BLOCK OF ICE.												
Outer layer, upper third.	None.	Sl't, dark-colored particles.	0.00	None.	None.	0 44	.0044	.0008	0.04	.000	.0062	0.0	.0073
Outer layer, middle third.	None.	None.	0.00	None.	None.	0.24	.0032	.0002	0.05	.0000	.0000	0.0	.0109
Outer layer, lower third.	V.slight.	Cons., white.	0.00	None.	None.	4.00	.0052	.0000	0.44	.1100	.0030	1.6	.0036
Inner core, upper third.	None.	Slight, white.	0.00	None.	None.	4.48	.0102	.0000	0.72	.1800	.0130	1.4	.0255
Inner core, middle third.	V.slight, white.	Cons., white.	0.00	None.	None.	14.76	.0262	.0016	3.27	1.0000	.0700	4.9	.0730
Inner core, lower third.	Distinct, white.	Heavy, white.	0.03	None.	Faintly, earthy.	70.00 61.10*	.0602	.0082	11.59	1.0000	.2800	21.0	.2993

*The second determination of the total residue of evaporation was made on the water filtered through paper in the laboratory.

conditions the impurities cannot be eliminated, but they are redistributed, the ice first formed being very pure, and that last formed containing nearly all the impurities.

In deep ponds we find the ice, which has formed slowly, to be of good quality even when the water itself is quite impure. In shallow bodies of water we should have very pure water and clean ground if the ice is to be above suspicion. In the case of artificial ice, it is absolutely necessary that the water should be of the highest purity. It would be seldom that a well or spring water could be found which would not give an objectionable degree of concentration of mineral matter in the portion last frozen. Distilled water leaves nothing to be desired as regards purity, and the manufacturers of artificial ice will find it desirable to limit themselves to its use.

In all cases of artificial ice which I examined there were practically no bacteria in the water used, or in the ice. It is the general practice in making artificial ice to boil the water in order to expel the air, otherwise the ice block would be very porous from air bubbles and would look more like a cake of compact snow.

OBITUARY.

SHERMAN E. GRANNISS.—Died at New Haven, Conn., August 10th, 1893, aged 58 years, 8 months. Joined this Association June 21st, 1882.

For eighteen years previous to his death Mr. Granniss had acceptably filled the position of superintendent to the New Haven Water Company. He was one of the twenty-seven who organized this Association at Boston, Mass., on June 21st, 1882. He took a deep interest in all its affairs, was a frequent attendant at its meetings, and was well known to all the membership. He served as member of the Executive Committee during the year ending June, 1885, and as one of the Vice Presidents during the years ending June, 1884, and 1886, and was an incumbent of that office at the time of his demise. He was a true friend and valued counsellor, and will be greatly missed in future gatherings of this Association.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VIII December, 1893. No. 2.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

FALL EXCURSION.

September 13th, 1893.

The fall meeting of this Association was held at Plymouth, Mass., on Wednesday, September 13th, 1893. The day was bright and clear, the temperature just right for bodily comfort, the picturesque scenery of Plymouth was displayed to its best advantage, and the hospitality of our Plymouth friends was bountiful. All present expressed themselves as having participated in one of the most delightful programmes ever given by this Association.

The members were met at the depot, on arrival of the trains shortly after 10 o'clock, by the members of the Plymouth Water Board. Barges were then taken and the first stop was made at the national monument to the forefathers. Thence a visit was made to Pilgrim hall and some time was spent in looking over the interesting relics of the Pilgrims. The next stop was made at Plymouth rock and Cole's hill. Explanatory statements, both historical and otherwise, were carefully made to the party at all of the above mentioned places by Charles S. Davis, Esq. The drive was then extended to the Pumping Station of the Plymouth Water Works, where the party was most hospitably received and cared for by Superintendent R. W. Bagnell. The neatness of the buildings and surroundings are worthy of special mention.

The company then proceeded to Hotel Pilgrim, located on high land about three miles south of Plymouth. A delightful sea view is afforded from the broad piazza of the hotel, and the air was so very clear that Race Point lighthouse on Cape Cod, twenty miles distant, could be discerned. At the close of the dinner and before the party had left the dining hall a vote of thanks was tendered the Water Commissioners and other citizens of Plymouth for the courteous attention shown the members of the New England Water Works Association and their friends. At 3 o'clock the party left the hotel to return to their various homes.

The following is a list of those who composed the party:

ACTIVE MEMBERS.

Richard W. Bagnell, Superintendent, Plymouth, Mass.; Lewis M. Bancroft, Superintendent, Reading, Mass.; Nathan B. Bickford, Superintendent W. W. O. C. R. R., Boston, Mass.; George Bowers, City Engineer, Lowell, Mass.; Dexter Brackett, Assistant Engineer, Boston, Mass.; John C. Chase, Superintendent, Wilmington, N. C.; Freeman C. Coffin, Civil Engineer, Boston, Mass.; R. C. P. Coggeshall, Superintendent, New Bedford, Mass; Lucas Cushing, Assistant Superintendent. Boston, Mass.; Edwin Darling, Superintendent, Pawtucket, R. I.; Francis W. Dean, Mechanical Engineer, Boston, Mass.; Frank L. Fuller, C. E., Boston, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; Frederick W. Gow, Superintendent, Medford, Mass.; Frank E. Hall, Superintendent, Quincy, Mass.; James H. Higgins, Superintendent Meter Department, Providence, R. I.; David B. Kempton, Commissioner, New Bedford, Mass.; Patrick Kieran, Fall River, Mass.; Horace Kingman, Superintendent, Brockton, Mass.; A. E. Martin, Superintendent, South Framinghom, Mass.; Edward C. Nichols, Commissioner, Reading, Mass.; Albert F. Noyes, Asst. Engineer State Board of Health, Boston, Mass.; George J. Ries, Superintendent, Weymouth Centre, Mass.; Henry W. Rogers, Superintendent, Haverhill, Mass., A. H. Salisbury, Superintendent, Lawrence, Mass.; M. M. Tidd, Hydraulic Engineer, Boston, Mass.; D. N. Tower, Superintendent, Cohassett, Mass,; W. H. Vaughn, Superintendent, Wellesley Hills, Mass.; A. H. Brodrick, Chadwick Lead Works, Boston, Mass.; F. H. Hayes, Dean Steam Pump Co., Boston, Mass.; Henry F. Jenks, Pawtucket, R. I.; N. F. Ryder, Middleboro, Mass.; J. C. Otis, Union Water Meter Co., Worcester, Mass.; George C. Duane, Portland Stoneware Co., Boston, Mass.; E. H. Rice, Walworth Manufacturing Co., Boston, Mass.; H. A. Gorham, The George Woodman Co., Boston, Mass.

GUESTS.

Mr. and Mrs. A. B. Alden, Middleboro, Mass,. John Alden, Middleboro, Mass.; Mr. and Mrs. Frank M. Ashley, New Bedford, Mass.; Mrs. Lewis M. Bancroft, Reading, Mass.; Mr. and Mrs. H. P. Bailey, Plymouth, Mass.; Mrs. Joseph E. Beals, Middleboro, Mass.; Mrs. Geo. Bowers, Lowell, Mass.; Mrs. Dexter Brackett, Boston, Mass.; H. D. Brackett, Boston, Mass.; Samuel Bradford, Water Commissioner, Plymouth, Mass.; Mrs. Freeman C. Coffin, Boston, Mass.; Mrs. R. C. P. Coggeshall, New Bedford, Mass.; Mrs. Edwin Darling, Pawtucket, R. I.; Mrs. F. W. Dean, Boston, Mass.; Charles G. Davis, Plymouth, Mass.; Mr. and Mrs. Charles S. Davis, Plymouth, Mass.; William T. Davis, Plymouth, Mass.; Miss Davis, Plymouth, Mass.; Mrs. F. L. Fuller, Boston, Mass.; J. C. Gilbert, Whitman, Mass.; Francis Greene, Providence, R. I.; Mrs. A. F. Hall, Boston, Mass.; Mrs. F. E. Hall, Quincy, Mass.; Mrs. F. H. Hayes, Boston,

Mass.; Mrs. James H. Higgins, Providence, R. I.; Mrs. Henry F. Jenks, Pawtucket, R. I.; Mrs. D. B. Kempton, New Bedford, Mass.; Miss Leonard, Middleboro, Mass.; Mr. and Mrs. L. D. May, Lowell, Mass.; Mr. and Mrs. Nathaniel Morton, Plymouth, Mass.; Mrs. Edward C. Nichols, Reading. Mass.; Mr. and Mrs. James Miller, Plymouth, Mass.; Mr. and Mrs. Charles Pike, Yonkers, N. Y.; C. C. Potter, Fall River, Mass.: Mr. and Mrs. N. Rand, Taunton, Mass.; Mrs. George J. Ries, Weymouth Centre, Mass.; Mrs. H. W. Rogers, Haverhill, Mass.; Mrs. N. F. Ryder, Middleboro, Mass.; Mr. and Mrs. E. F. Sherman, Plymouth, Mass.; Miss Smith, Cohassett, Mass.; J. C. Sullivan, Middleboro, Mass.; Miss Sylvester, Middleboro, Mass.; Mrs. D. N. Tower, Cohassett, Mass.; Charles J. Underwood, *Engineering Record*, New York city; Mrs. W. H. Vaughn, Wellesley Hills, Mass.; Miss Wentworth, Lawrence, Mass.; Mr. and Mrs. G. E. Williams, Weymouth Centre, Mass.

"IS THE GAME WORTH THE CANDLE?"

BY

JOHN THOMSON, M. Am. Soc. C. E., New York.

(Read June 14th, 1893.)

It seems desirable and even necessary to make a brief explanation regarding the published title of this paper. The courteous invitation, extended by President Chace, to prepare a paper for the summer meeting of the New England Water Works Association, found the writer at a loss for a subject, even although no reservations were made as to its selection, and floundering around, as it were, at last replied, in effect, that he hardly thought "the game worth the candle," meaning to convey, of course, that the illuminator in this case would be our Association, while the "game" would be the writer, should he come before you. But either the ability to comprehend a joke in Massachusetts is as obtuse as that fellow Scott who required to undergo the surgical operation of trepanning to take in the point, or else this is a case like Hamlet's, in which "the engineer is hoist by his own petard." But when, moreover, it was strongly intimated that a member of this Association would be liable to expulsion should he decline an invitation which, at the option of the guest, might have a *liquid* termination, it is doubtless needless to mention that the invitation was forthwith accepted. It is now proper to say that in attempting to fit this paper to your President's title, the limited time at disposal has rendered it necessary to draw upon a previous effort; so that the paper in fact will consist of a few brief opinions and observations in relation to features connected with the Commercial Side of the Water Meter Question.

The assertion is first ventured that there are fifty water works men today where there were but five ten years ago, who not only strongly believe in and advocate the use of water meters in general, but who also believe that every new service connection ought as uniformly to be provided with a meter as with a stop-cock. Undoubtedly, however, the element of cost is a considerable limitation to such a general introduction and use of meters. And this at once leads to a second assertion that the principal limitation to the reduction of prices for water meters is largely due to the two following conditions, namely: the degree of sensibility required at low rates of flow and the capacity to also safely operate under conditions involving high rates of delivery.

For years the writer has been searching for small things—the fine edge in first principles; the obscure detail which in the fabrication of mechanical devices is so often the key which opens the door to success, or gives a logical reason for a failure. But what should be the measure of the value in such cases, the mere finding of the thing itself, or that which it produces? And what should be the limit; for in mechanical refinement, as in the vastness of

space, "end is there none." From the high plane of scientific investigation, pure and simple, there is, of course, only one reply; but from the medium line of commercial considerations the answer may not be so certainly given. If we have many times to change the value of cubic feet into United States gallons for the purpose of comparison, does it repay the consumption of phosphorus and of time to multiply by 7.48 instead of 7.5 when it is the comparison of numbers and not the accuracy of the result in gallons that is sought? Does it pay, if desiring to know the circumference of a hemlock log, we multiply by three and four decimals, then peel off the bark and make no allowance for *tare*? Please do not by this conclude that the writer would belittle the value of the decimal point; its importance can hardly be over-estimated. But it is to the disposal thereof that we are now contending, for it is a nice thing to know on *which side* of the full number to wisely place it, whereby to obtain the most economical results, when judged from the stand-point of every-day common sense requirements.

And with these reflections in mind it will readily be apprehended that the topic selected may be variously applied. For the time being, then, the writer would be regarded as a Public Economist in Water Works Equipment and the first application of our caption to be this:

For ordinary domestic service, is a high degree of sensibility in water meters at low rates of discharge worth what it costs? In other words, is the revenue derived from the measurement of "driblets" a sufficient compensation for the additional cost of the investment? "Is the game worth the candle?" As the writer has before adverted to this subject in a paper entitled "A Memoir on Water Meters," presented to the American Society of Civil Engineers, and which his eminent friend, Mr. Emil Kuichling, M. Am. Soc. C. E., Chief Engineer of the Rochester (N. Y.) Water Works, discussed with partial reference to placing the decimal point on the left hand side of the numeral, a few excerpts from the paper and its discussion, taken from the Transactions of the American Society of Civil Engineers, Vol. XXV, June, 1891, may not be here out of place, the more particularly so as it was these portions of the paper which received the most extended notice at the time of its presentation.

In regard to accuracy in the registration of meters, the following excerpt is quoted:

"In Europe the necessity for economy in the public meter service is probably accountable for the much greater use of meters which there exists than in America. It is certain, too, that the employment of meters abroad has resulted in a satisfactory reduction of the water-waste, notwithstanding the fact that this has been largely accomplished by the use of the low-priced and comparatively inaccurate types of inferential meters. Hence, there is here presented the apparent necessity for close measurement, but with satisfactory economical results being derived from the employment of what is generally conceded to be the most inaccurate type of domestic water-measuring instruments.

"With us, however, it is but a slight stretch of poetical license to say that, when the water works engineer, who for years has stood complacently by

while water has been wastefully served at from 75 to 150 gallons per capita per day, who then suddenly concludes to apply a few meters to check this lavishness, his economy goes not only to the dollars but to the pennies; the meter is required to measure down to drops, and a standard of accuracy is not infrequently set up which but few laboratories have the means of verifying, and fewer water works employes the ability to carry out.

"The point of this is that for all practical purposes, in ordinary public service, a meter which would register to within 5 to 7 per cent. of accuracy, between fair minimum and maximum rates of discharge, is, in the writer's judgment, as in that of many others, amply accurate to effect the desired purpose. And when our water works officials will have arrived at the same conclusion, meters may then be purchased at a discount from present prices of from 20 to 25 per cent. Furthermore, such a standard of accuracy would, in ordinary practice, result in decreased cost of maintenance and increased life to the meter, because of the practical conditions of service under which meters are frequently set."

A portion of Mr. Kuichling's admirably prepared rejoinder is quoted as follows:

"While it may be conceded that the only rational way of charging and paying for water consumed by individuals or corporations is by meter measurement, yet the present cost of these measuring devices and their maintenance is generally regarded as being altogether too large to render their extensive introduction expedient in our large cities. Many water works officials would doubtless cheerfully recommend, and perhaps strongly urge, the adoption of meters for all classes of consumers, if they could obtain reasonably accurate, sensitive and durable machines at somewhat lower prices than appear to prevail at the present time; and it is mainly in consequence of existing prices, which the public regards as too high, that all efforts to introduce a general meter system have, in the majority of cities, met with determined opposition.

* * * * * * *

"It is very justly said that water is not sold to consumers by the drop or driblet, but by the gallon or the cubic foot, as the smallest practical unit. To this statement no one should take exception, but it is also fair to take it literally. Let the meter be sensitive enough to record, even with wide margin of accuracy, the fact that hundreds of gallons pass through it in the course of a day, and it will be a far more useful instrument to the community purchasing it than one which will exhibit marvellous accuracy in the measurement of comparatively large streams, and yet allow small flows to escape without detection. The percentage of error in registration of a meter is therefore a matter which should be sharply defined, and should be made dependent upon its sensitiveness. * * * * * *
In the case of meters intended for family use, which in a general meter system would vastly outnumber all other kinds, it is, therefore, essential to make sensitiveness a paramount feature, as well as durability and cheapness. The same requirements may also be made for meters for the majority of manufactories and places of business in a community; and in the comparatively

few instances where the draught is constantly large, special meters which give a high degree of accuracy can easily be applied.

"In conclusion, therefore, it may be stated that a thoroughly serviceable meter would have a large sensitiveness, but need not have a very high degree of accuracy. How these qualities can be combined with durability and economy is a question whose solution is left to the skill of inventors."

To Mr. Kuichling's discussion, still referring in particular to the matter of accuracy, the following reply was made:

"As to lowering the standard of accuracy, this is a suggestion which I made with considerable hesitancy, as it might be taken as appearing to advocate a step backward. Nevertheless, I am of the opinion that, in at least the great majority of instances in which meters would be comparatively largely employed, the fact of whether or no they indicated at comparatively low rates of flow would bear but a very small relation to the total advantage and revenue derived therefrom. The point made by Mr. Kuichling to permit a lowering of the standard of accuracy, while yet retaining the element of sensitiveness to such a degree as to at least indicate a portion of the entire quantity at the lowest practicable rates of discharge, is somewhat in line with the results obtained in the use of the low-priced inferential meters, a type but little known in this country. This is a condition of operation, however, which would probably be very difficult to obtain, if at all, in the existing types of positive displacement meters."

In the first of the foregoing quotations the point was not made as clearly as it should have been, that an accuracy limit of from 5 to 7 per cent. was intended to refer in particular to operations at low rates of flow, because it is a fact that nearly, if not all, of the existing types of positive displacement meters may be calibrated to indicate with practical accuracy through a wide range in rate of delivery, although not capable of registering at a predetermined low rate of flow. The reason for this is that until the static resistance of the device is overcome, the freely fitted parts permit leakage, but immediately the mechanism is put into operation the error, if represented graphically, as by a line, would rapidly rise until at and beyond a given rate of flow the leakage, or "slip," as it is termed, becomes practically constant and will remain so, provided excessive wear of the parts does not take place. Now, in the instance, say, of a tightly fitted piston, or any equivalently positively operated device, which requires a considerable difference of pressure to operate it, the tendency is at once increased to cause leakage, or increase of "slip," and by this very fact to increase the likelihood of carrying particles of fine dirt or sand between the bearing surfaces. Again, the immediate consequences of such introduction of foreign particles is, by action analagous to that of a wedge, to still further increase the resistance of the device and wear of the parts. Thus in a machine, the first and the desirable effect of wear upon the journals is to bring the surfaces into more intimate contact by working down the high parts which first impinge against each other; but in a meter, referring to the instance being illustrated, the opposite effect is incited, that is to

decrease the intimacy of contact and provide a free film of water between the parts.

There are thousands of meters in actual service today performing well, returning a satisfactory account of their stewardship and earning a proper revenue, which if now tested at many of the low rate requirements would not pass muster and yet there has been accomplished upon the meter by wear of its parts what had probably been best definitely performed mechanically, that is, its bearings have been ground to a clearance.

What has just been said refers, as it will of course have been understood, to meters set under ordinary direct service, which is the only proper condition to which modern compact "rotaries" and also many of the "piston" types of meters, are adapted.

Now, the writer is not prepared to take a strong position upon this matter, rather hoping to derive information from the discussion of others more competent, nevertheless, he is strongly inclined to the opinion that, for the regular direct domestic service, a comparatively slight lowering of the usual standards of sensibility in the presently popular "rotary" meters would be of mutual advantage both to the purchasers of such meters, and to the manufacturers thereof. And attention is called to its being a "mutual" advantage, as the writer does not pretend to come before you with a scheme involving either charity on the one hand, or the missionary element on the other. The advantage to the purchaser would be in increased durability and decreased cost, the two, being of greater value, probably, than the quantities lost by lessened sensibility. The advantage to the manufacturer would probably be in the increased demand for his product; which, when taken together with the decreased cost of manufacture and calibration, would more than compensate the reduction in price. Consequently, the benefit would be *mutual.*

The extreme positions taken on this subject by engineers of recognized ability, is a lesson in the power of human judgment to distend without passing the "elastic limit." Thus, in a further discussion of the paper referred to, Mr. D. McN. Stauffer, M. Am. Soc. C. E., formerly city engineer of Philadelphia, said editorially in his paper, "Engineering News," as follows:

"In a memoir upon water meters, read last week before the American Society of Civil Engineers, at Lookout Mountain, Mr. John Thomson justly remarked that there is a demand on the part of corporations for altogether too much accuracy in water-measuring machines. He says that an error of five to seven per cent. would really be unimportant when the essential purpose of a water service is considered; and that the resulting gain from this allowance of error would be a much less costly and yet a more durable meter. We fully agree with Mr. Thomson. Water is sold by the gallon and not by the drop, and the only reason for measuring it out through a meter is to closely approximate to the actual quantity furnished, and to thus check the wholesale waste prevalent under the older methods of service. A few hundred gallons more or less, in a year, in the amount furnished to a consumer, is of little real importance; but it is important to stop the same man from absolutely wasting thousands of gallons in the same period. Water is a commodity that

should be made as nearly free as possible for all legitimate use; and a serviceable meter is the best regulator of this legitimate use. Its utility is fully recognized by all purveyors of water, and the comparatively expensive character of the machine and the cost of keeping it fully up to established standards of accuracy are the only limits to its common adoption. If the small error mentioned by Mr. Thomson will enable the price to be reduced from 25 to 30 per cent. below present market prices, and at the same time furnish a meter that will cost less in repair, there seems to be no good reason for rejecting his advice. A change of this kind would at once vastly extend the use of meters, and no one can question the gain in waste prevention, as compared with the older and very reckless methods of furnishing water. With only six meters, as yet, to every 100 taps in the United States, our readers can judge for themselves of the field still to be covered by this useful regulator of domestic and general water supply."

Then my good friend, and thoroughly practical engineer always, Mr. Robert Cartwright, M. Am. Soc. C. E., basing his judgment upon an experience with some tens of thousands of *gas* meters, says that he is prepared to reduce the water waste to a satisfactory rate by the simple use of meter *casings*, having no internal mechanism whatever; upon the theory that the *moral effect* upon individuals who suppose that the water which they are using is being measured, would have the desired result. On the other hand, Mr. Kuichling has pointed out, with an incisiveness which may well make the "meter man" wince, that the maintenance of meters "is generally regarded as being altogether too large to render their extensive introduction expedient in our large cities." And yet the requirements which he would insist upon are precisely those which both increase the cost of the meter and render it more likely to become damaged in practice. The query may well be here injected, if the saving in first cost and in cost of maintenance were invested in additional meters, would not the sum total of receipts and results be upon the side of the municipality?

It will be observed that the writer has made no suggestion as to what the proper minimum rate of test ought to be, believing that this can best be answered by the membership. It involves several interesting points, and so far as he knows has never been considered with the view of establishing uniformity of practice.

The second application refers to an opportunity open to the purchasers of water meters, and one which is almost entirely to their advantage, having in mind the existing state of the art. This refers to the selection of the proper size, or capacity, for the minimum service intended. In the aforementioned paper this was briefly referred to as follows:

"One of the most difficult experiences met with in practice has been to make clear to many water works superintendents that, in selecting the size of of a meter, conditions of operation have frequently much more to do with the quantity discharged than the mere matter of pressure." * . * * * "From whence it follows that probably three-fourths of the meters in public use today are considerably underworked; and that, if

proper judgment could be depended upon in selecting the capacity of the meter to the duty to be performed, still more compact and less expensive nominal sizes might be the result "

The opinion then expressed has been but strengthened by experience meantime gained; and while there is no more exasperating and inexcusable fault than to set a meter so as to be damaged by over-running, a fault promptly made evident, but little is ever said or known regarding the opposite condition, that is, under-running, which prevails to a much larger extent than is generally supposed. The reason for the latter is probably too often due to the greater convenience of measuring the diameter of the pipe, to which the contemplated attachment is to be made, rather than measuring the quantity which the pipe can deliver.

The writer believes that there is but one reliable and satisfactory method for practically determining the proper maximum capacity of a meter to be applied to a service, namely: to insert a meter in circuit, open all the valves or faucets and *time the operation of the meter* for one, five or ten minutes. Thus, if a $\frac{3}{4}$-inch meter has been set and its full delivery is only, say, $1\frac{1}{2}$ cubic feet a minute, then in the majority of cases a $\frac{5}{8}$-inch meter would satisfactorily replace it and so on through the range of sizes.

The proposition has also been previously set up by the writer that in his "belief and judgment, the proximate increase of efficiency in water meter practice will come quite as much from the better knowledge and practice of water works employes as from direct improvements in meters by manufacturers and engineers." And the points just made in regard to the selection of a proper capacity of meter, the one best suited, not to the diameter of the pipe, mayhap, but to the volume which it will be required to deliver, is directly in touch therewith. A new engine is not selected for an old factory by the diameter of the existing main-shaft, but upon an approximately definite knowledge of the machinery to be driven, and the power necessary therefor. But this illustration ends here, for in the instance of the engine, the required power may be predicted within the range of practical requirements, while in the case of the meter, a formula is yet to be written which will disclose the interior condition of valves, "department" stop-cocks, and such service pipes as have received the usual supply of plumbers' "trade marks." Hence, the expressed opinion that there is but one reliable plan to follow, at once convenient and eminently practical, namely: to apply the meter, time its delivery, and thereby ascertain its rate of operation, The commercial advantage of closely looking after this feature of meter practice will be almost entirely on the side of the purchasers of meters. In many cases where a meter smaller than the pipe is selected, it will have a two-fold advantage, effecting both a reduction in the first cost and by deriving the increased sensibility of a smaller instrument.

Regarding the maximum capacities of meters as published by the different meter companies, they in fact mean but little, and are often deceiving and disappointing. It is like saying, Given the requisite head, and the supply, and the conditions, and we will blow as much water through a nozzle of 2 inches

diameter as the other fellow with a nozzle of $2\frac{1}{2}$ inches diameter, the mental reservation being made, however, that "we" will design and fabricate both of the said nozzles! The table of greatest proper quantities per minute, promulgated, it is understood, by the late Henry R. Worthington, is probably the nearest to a proper scientific basis—that is, velocity of flow through the pipe—of any known to the writer, as the controlling merit of those tables which have been developed more recently, would seem to be in the higher figures employed. Such tables may be taken as representing the very highest rate of operation at which the meter should be operated under extreme conditions—as in increased pressure for fire service—while for any fairly uniform rate of delivery all published maximum rates should be considered as in the case of list prices, *subject to discount.*

The third general application has reference to the matter of obstruction to the flow; which is often an important one in meter practice, and in this connection it may be well to call attention that the mere exhibition of a meter-device operating under a slight head, or by blowing or exhausting, should be understood as simply demonstrating the mechanical resistance of the parts, and is quite independent of the loss of head which may be due to tortuous water passages, or restricted ports. The complete and ready demonstration in such cases, where it is necessary or desirable to know the extent of the obstruction, is to note the time required to discharge a certain quantity into a trial-tank both with and without the meter in circuit, being careful to observe that *all* the conditions of each test are identical.

In conclusion, a few general observations, not to say, predictions, may be admissable. As in surgery, mechanics, engineering and the arts, sub-division of the art and sub-division of the section has resulted as well from necessity as from adaptation and desire. The day has surely passed when an admiring community shall pause awe-struck before an individual, because possessed of the universal knowledge of his time, and of whom it was recorded:

> "And still their wonder grew,
> To think that one small head,
> Held all he knew."

The day of division in the selection and use of water meters is at hand, if the water works purveyor would obtain the most economical returns, for there is no meter now on the market, nor is there much likelihood of its being devised, which will at one and the same time give equally satisfactory results under all conditions, when measured by the gauge of economics. From whence it follows that special services require as fair an exercise of judgment in the selection of the meter for the duty to be performed, as in the instance of a pump designed to feed a boiler, or to drain a mine.

In a table prepared by the writer in 1891, for the already too frequently mentioned paper, it was shown that the relation of meters to taps in the United States was only slightly over 6 per cent. This was subsequently taken up by one of the technical papers and, according to present recollection, the relation which it found was about 7 per cent. These figures were

obtained from the most reliable source then at hand, and were probably the first compilations of the kind ever made. They will be of particular value, however, should the opportunity again be taken to make a comparison at a yet later date; as it is the belief of the writer that, although from 35,000 to 40,000 water meters are now being made and sold every year in the United States, the water services are nevertheless probably being increased at nearly, if not quite, as rapid a rate as is the application of meters. Consequently, unless the production of meters shall be increased at even a much greater rate than heretofore, it would then be fair to assume that the ratio of meters to taps will not materially change.

But the writer trusts and holds that this relation will not remain constant; he would not be a consistent member of the Colony of Meter "Cranks" if he thought otherwise. He believes that the increasing use of water meters is a Public Benefit; that the suggestions herein contained, were they but partially carried out, would result even more beneficially; moreover that such benefits would be mutual; and hence, the "game" may be "worth the candle" to us all.

DISCUSSION.

Mr. Walker. I would like to ask how it would be where a tank is used? You say the meter might be made cheaper and more durable if it was not designed to register very closely. Where water is fed into a tank and afterwards drawn from faucets, the water can run slowly into the tank. Wouldn't a person get more than his money's worth of water in that case?

Mr. Thompson. I think you are right. I particularly specified in the paper that I referred to the direct connection of meters in regular service, and I had in mind just such a condition as you mention. In a case of that kind it requires as close a degree of sensibility as is possible. It is one of the most difficult conditions found in practice—tank service such as you refer to; and I did not have that in my mind when I suggested lowering the senisbility as set forth in the paper.

The President. Mr. Brackett has had a good deal of experience in testing meters, and we would like to hear from him.

Mr. Brackett. I would say that I agree to a large extent with Mr. Thomson's conclusions. I think that while there might be some loss by the use of meters of a less accuracy, yet, as Mr. Thomson says, the proportion of loss would be very slight as compared with the total amount which is measured. The great objection to the adoption of such meters would be the tank service; and as the tendency in a great many cities now is to oblige the use of tanks in all cases, the difficulty there would be a practical one. However, even with a tank service I think the meter would register a very large percentage of the total amount used. The statement made by Mr. Thomson in regard to the small proportion of services which are now metered, is, I think, somewhat misleading, because what we really wish to know is the quantity of water which is used, and while the percentage of taps that are metered is only six or seven the proportion of the consumption used through meters is much larger. In Boston about seven per cent. of the taps are

metered and something over 27 per cent. of the total consumption. In New Bedford only 2 per cent. of the total number of services are metered but they meter between 20 and 25 per cent. of the total consumption. The proportion is larger there than in Boston. The fact which I have noted is that in 1890, New Bedford, with 140 meters, metered more water than Fall River, with 3,700 meters. The probability is, especially in the case of large meters, that the loss through an inaccuracy of five per cent. would be very small.

Mr. Walker. We buy our own meters and furnish and set them for nothing, and we have got a mimimum rate of $12. I am satisfied it does not pay, if you have plenty of water, to look after those meters and furnish the water for $12 a year. If you have little water it might pay; but if you have plenty of water it don't pay to look after a meter and keep it in repair, as they are making them now, for $12 a year. I think we should have a fifteen or twenty dollar rate, as far as our city is concerned. We have a good deal of trouble with our meters, and it makes no difference what kind of a meter it is, I think we have all kinds, and we have trouble with them all. But they are all accurate enough to detect a leak.

AN EXPERIENCE WITH A STAND-PIPE.

BY

JOHN C. CHASE, Superintendent, Wilmington, N. C.

(Read June 15th, 1893,)

The system of water works which the writer has in charge, was constructed some twelve years ago, and was among the very first built on the franchise plan. Two local capitalists were interested in the scheme, by an outside party, whose chief end was, apparently, to secure the contract for constructing the works. A valuable concession and contract, for a term of thirty years, was secured from the city, and, in due time, the same was transferred to a company organized under legislative charter.

The works were built without any engineering advice, so far as the owners of the system were concerned, except that furnished by the interested contractor. A local surveyor was employed, and given the title of engineer, but it is hardly probable that he had ever seen a water works plant, and all he apparently did was to sign such certificates as were prepared for him, and draw his pay.

One feature of the system was a stand-pipe twenty feet in diameter, and seventy feet in height, which was nearing completion when the writer arrived to take charge of the works.

This structure was a plate-iron cylinder, made of sheets three feet in width, and having a 6"x6" angle-iron on the lower edge, with the horizontal leg turning outward. It was erected on a masonry foundation without any anchorage, and without any bottom, the latter being replaced with an internal layer of cement concrete about one foot thick.

The parties who furnished the material say that they "gave the contractor a price for the complete structure, which was afterwards reduced in consequence of leaving out the iron bottom, which was his own suggestion."

The cause of this change is well understood by the writer, but it does not call for explanation in this connection.

The concrete bottom did not prove to be water-tight, and was taken out.

The next move of the builder was to pick out a recess under the bottom of the angle-iron, and pour a lead joint entirely around the outer circumference,

expecting to be able, by calking, to make a tight joint between the metal and the masonry. As might have been expected, this was a lamentable failure, and recourse was had to a new layer of concrete.

Before this was in condition to use, the contractor deposited, with disinterested parties, a sum of money sufficient to provide an iron bottom in case the concrete was not satisfactory, or did not remain tight for a period of six months, and having, in the meantime disposed of his stock interest, retired from the scene, stating, however, that he was going to arrange for the immediate putting in of an iron bottom, in order to release the funds deposited.

Nothing further was heard from him, and the six months clause turned out to be merely a device to embarrass the Water company in the use of their property, but, in due time, they gained possession, and the first question was how to complete the work in a water-tight and workmanlike manner.

The treasurer of the company, who was also one of the largest stockholders, was a lumber manufacturer, and like the historic tanner, who believed that there was "nothing like leather," saw no reason why a wooden bottom would not be the correct thing, and proceeded to carry out his ideas, although the writer did not approve of the device.

This is one of the few cases where the "practical man" has scored an apparent victory over the engineer.

The bottom was made of two thicknesses of three-inch yellow pine plank, laid so as to break joints, all joints being filled with oakum, and then coated with pitch. The surface of the concrete was leveled up with a bed of cement mortar, on which the bottom layer of plank was bedded. Short braces, bearing against the bottom of the second course of sheets, were put in to keep the bottom from floating until it became thoroughly water-logged.

The leakage has been slight, and has not varied to any perceptible extent, except for a short interval after refilling the stand-pipe, when it has been emptied for any purpose.

As before stated, the writer did not approve of the method adopted, and claims no credit for its practical success.

It is perhaps unnecessary to say that notwithstanding the satisfactory result, he would not advise its future adoption, though a state of affairs requiring similar treatment can hardly be imagined to exist.

Inasmuch as the expense was less than one-fourth of the sum required for an iron bottom, the experiment was a *financial* success, and the members of this Association are probably well aware that such results appeal far more strongly to the heart of the average capitalist than any amount of abstract theorizing from an engineering point of view.

The prospective removal of the structure to a different location is anticipated with pleasure, as it will give an opportunity to complete it in accordance with long tried and approved methods.

Further comment is unnecessary, and each one can point the moral to his own taste.

In conclusion, it may be said that the stand-pipe was soon found to be of inadequate height, and an addition of twenty feet was made to the top.

The inside staging having been removed, and the outside one being considered unsafe, the extension was erected from a float containing a balance derrick, which enabled the sheets of a course to be raised and swung to the proper position in a very expeditious manner.

The rivets were driven on the inside, and held on the outside by a workman suspended in a cage, carried by roller hooks traversing the top edge of the course of sheets, on which work was being done.

The riveting of the course having been completed, the seams were calked, and water then pumped in until the float was raised to the desired height for another course.

This method of construction has the advantage of testing the work as fast as completed, and the writer believes this to be the first time the method was used. It has been in frequent use since, and is of great advantage where the pumping machinery and connections are completed before the stand-pipe is erected.

.WATER PIPE TRENCHES VS. GOOD ROADS.

BY

W. E. McClintock, C. E., Boston, Mass.

(Read and illustrated by stereopticon, June 14, 1893.)

The wants of modern civilization are many, and the civil engineer has to be often called upon to satisfy some of these. If we cast a glance backward to the beginning of the present century, we shall see that about the only demand for skilled engineers was in laying out and constructing canals. The same men who gained experience in this line of work naturally took charge of the steam railroads, when their construction began, shortly after the close of the first quarter of the century. Near the middle of the century, the important question of obtaining a supply of water from outside sources was inaugurated by Boston; and not long after, it became imperative to remove the increased wastes, and sewerage began to assume importance. Today, every town of any considerable size has its water works, and they are fast putting in sewers. Then came gas, electricity, and various other new works; and quite recently the engineer has been called upon to take up with highway engineering. While our own country was passing through the canal-building period, the foreign engineer was at work improving the highways as well as water-ways. During that time the two eminent Scotch engineers, Telford and Macadam, started out on their grand work in Great Britain; while the School of Roads and Bridges was being organized for the same kind of work in France. It was during that time that road building became an art; and even before the advent of the steam railroad, Great Britain France and Switzerland had succeeded in constructing a network of magnificent highways, many of them on the ruins of the imperial roads of Rome, which had in many cases been disused for centuries. There can be no doubt but what the present agitation in our own country will not be dropped until our roads are the equal of any country in the world. We have the money, the materials, and the brains, and it looks now as if these are to be mixed in the proper proportions. The civil engineer is often a destroyer, as well as a builder up. Water works, sewerage works, gas works and street railways are certainly most destructive of good roads. In all of these works, the civil engineer has a hand at the very start, an inspection during construction, and a final approval; and it lies with him, to a large extent, to say what shall be and what shall not be done. It is surely a short-sighted policy which will not allow us to see beyond the work directly in hand, to a work of nearly, if not quite, equal importance. It is our duty to respect all kindred works, and do all within our power to maintain, if not improve, them. What is the general practice of most of us as superintendent of water works, when our duty calls

us to lay a water pipe, either main or service, and in so doing dig up a street? What do we do with the trench? I have taken a few pictures of such trenches as they were left, and they will look familiar to many of you, I am sure.

Here is one near a hydrant, where the wheel sinks in over eight inches, and large stones lay scattered about the ground. The road on both sides of this trench is good and smooth, and the first intimation I had of the hole was when my wheel went into it, and I nearly broke both neck and wheel.

Here is another hydrant trench, cut in a good, hard roadway, on a street lined with fine residences. The back fill was made without any attempt at ramming, or care in covering large stones, and over the trench it was humped up five to six inches with a coarse, loose gravel, some of the gravel stones being four to five inches in diameter. This gravel will not compact inside of four to six months, and when it does, there will be a deep hollow in the middle, and a ridge on each side, where the gravel has been crowded out over the firm ground.

Here is a trench through a firm, smooth, macadam road; an old pipe was taken out, and a new one of the same size put in. All our text-books tell us that excavated earth shrinks when put into another place; but this shows a ridge along the road which is fully three inches high. The whole road is disfigured, and will remain so, perhaps, for years. Here is a picture of a main being extended across a road. The back fill is loose gravel and coarse stones, an eyesore to the abutter, a menace to the unwary traveler.

I say such things are wickedly wrong; all the more so, because they are so easily preventible.

We know there are two kinds of water trenches,—the new, clean trench, and the one caused by a broken main.

The new trench, when properly back-filled, should be a benefit to the roadway, as it often affords much needed drainage. I have often seen the part of a roadway over the water trench dry and hard, when the rest of the way was almost impassable. This resulted from putting all the stones at the top of the trench, just below the surface, where they served the purpose of a Telford foundation, and afforded excellent drainage.

I should say that the first step for you to take, as water works men, would be to pay strict attention to this part of the work. It would add but little to the cost of your work, and would place you in the ranks of road-builders, instead of destroyers. In excavating, first have the upper few inches of a roadway carefully laid to one side, the remainder of the excavated material on the other side of the trench. While this is ordinarily intended to be done, there are but few cases in practice where it is strictly attended to, and even though it be, no good will result, as the bottom of the trench may not be rammed, and it is an even chance if the original top layer will not be carried away. In case of a break, the light material is washed out, and the stones are at the bottom of the trench, or the whole mass of earth is saturated with water, and entirely unfitted for back-filling. This is particularly true during freezing weather.

The only remedy for such cases that I know of is to remove the water-soaked material, and put in its place dry gravel or other material, and carefully ram it. If the gravel used be loose and clean, it may be compacted easily by spreading over the top a covering of dirt, free from stones, and then ramming carefully, leaving the surface as near even with the original roadway as possible. If the roadway be macadam, broken stone, properly screened, should be placed on top and rammed thoroughly, and covered with from one to two inches of stone dust.

You may say, "this is no part of my business as superintendent of water works." But I say it is your business to leave things in as good condition as you find them; and until you do this, you have surely failed in your duty.

Some good authority states that earth moved from bank to fill, shrinks, the shrinkage varying with the material, it being greatest in puddled clay and least in gravel.

TABLE OF SHRINKAGES OF EARTH.

Gravel	8	per cent.
Gravel and sand	9	" "
Clay	10	" "
Loam	12	" "
Puddled clay	25	" "

In a small experiment, I excavated a trench in a clayey loam to a depth of one and one-half feet. The back-fill was rammed dry, in layers of not over three inches, and the excavated material filled the trench within two inches of its top, or about 11 per cent.

In case we were to lay a 12-inch pipe in a trench $4\frac{1}{2}$ feet deep and $2\frac{1}{2}$ feet wide, the shrinkage should be .59 of a foot deep, or 1.475 square feet in section, which is equivalent to a circle of about $1\frac{1}{3}$ feet. If this is correct, we should lay on 12-inch pipe, put all the excavated material back, and leave no ridge on the surface.

In putting in some pipes for storm-water sewers in Belmont, our specifications were that the trenches should be carefully and thoroughly rammed, all the excavated material being put back, and the surface of the roadway be left even and smooth, with no ridge. The pipes varied in size from 8″ to 12″, and the work was done as specified, although I had strong doubts of it at the start.

Different materials must be back-filled in a different manner. I have made a few crude experiments in this direction, which may have some value.

The three trials I will refer to were as follows: with clean gravel; gravel containing more or less clay and loam; and fine hard pan or boulder-till.

First experiment: with clean gravel. The gravel was all placed loosely in a tub, and was 5.33 inches deep, after ramming dry. A second trial was made by ramming in layers of about two inches, which resulted in leaving the depth 5.3 inches. A third trial was made, which consisted in placing the gravel in layers of about two inches, wetting just enough to moisten, and ramming each layer; the result was just the same as by the last method.

Clean gravel or sand will unquestionably pack closer when dry than it will when it is wet.

Haswell gives the weight of a cubic yard of dry, loose sand as 2632 pounds, and of damp sand as 2349. That is, the dry sand will weigh about 12 per cent. more than the damp, provided it is put in loose, without ramming.

The experiment referred to above shows a settling of about one-half of one per cent. by ramming in thin layers, and this was not changed by applying water, either in large or small quantities.

If all the fragments which make up a gravel are in close contact, there can be no future settlement. But it is possible to have a good percentage of quite fine sand intermixed with the larger fragments. If the mixture is perfect, the smaller bits will fill the interspaces of the larger, and there will be no settlement. The difficulty is to secure a complete mixture of all the different sized bits, and at this point we find the ramming comes into play. By jarring the whole mass, the finer sand is sifted down so as to fill the voids. This process might be assisted by water; but I should say that it should be applied in large enough quantities to wash the finer bits down. There is no doubt, in my own mind, but a trench in sand or gravel can best be back-filled without water and with a moderate amount of ramming.

Second experiment: with gravel containing more or less clay and loam.

The material used for the experiment was taken from a trench which is now being worked on, and I will show you pictures of the way in which the work is being done.

The dry gravel was all placed in a tub, and was 6.23 inches deep. It was thoroughly rammed, and then measured 5.75 inches deep,—a shrinkage of 7 $\frac{7}{10}$ per cent.

The second lot, dry, was then rammed in two inch layers, and measured 5.4 inches,—a shrinkage of 13 $\frac{3}{10}$ per cent. from the loose material, or 6 per cent. of the single rammed. The gravel was then placed in two inch layers, each layer was wet to moisten the material, and then rammed. The depth was thus reduced to 5.2 inches, or 3 $\frac{7}{10}$ per cent. of the dry ramming in thin layers. A thorough puddling and ramming reduced the depth only about one-tenth of an inch more.

The deduction I should make from this is that gravel and clayey earth can best be settled by a thorough ramming in thin layers, while dry or slightly moist.

Any ordinary trench can and should be so rammed that all the excavated material back be returned and leave no ridge.

If you wish to make a particularly good job, as far as the roadway is concerned, let your men throw the finer stuff into the bottom, leaving the coarser stone to fill the top six or eight inches of the trench, covering this with one or two inches of fine gravel. In this way you can make a good strip of road, even if the rest of it is bad, and it might serve as a penance for past sins of commission.

Third and last experiment: with hard-pan or boulder-till.

As many of you know, a trench through hard-pan is one of the most difficult to put back so it will not settle. The lumps of sandy clay are hard, and when thrown into the trench they lie like so many stones; but unlike stones, they will dissolve in water, and forming, as they do, a very porous mass, the water finds its way amongst them, and they gradually slack up, settle together, and cause a great deal of trouble for many months, if not for longer periods. If we can break these lumps up to a powder, there will be no future trouble. But while they appear to be quite fine, there are yet many interspaces which allow of settlement.

I first filled the tub with dry hard-pan, and rammed it thoroughly, when it stood to a depth of 6.1 inches. It was again placed dry, in thin layers, and each layer rammed, when the depth was reduced to 5.6 inches, or an $8\frac{2}{10}$ per cent. reduction from the single ramming.

It was next placed in thin layers, slightly moistened, and each layer rammed, when the depth was reduced to 5.5, or $1\frac{8}{10}$ less than the dry, thin layers rammed.

The whole was then shaken up and made quite damp and rammed thoroughly. The depth then stood 4.93 inches, or 12 per cent. less than the dry, thin layer ramming, and $10\frac{2}{10}$ less than the moist thin layer ramming. It is evident, from this, that the lumps of hard-pan are best broken up by a good moistening and a thorough ramming. The lumps are sufficiently fine to resist the action of water for some time; but while damp, they are easily acted upon by the rammer, and reduced to a sufficient degree of fineness not to settle any more.

I should dry ram all trenches thoroughly, using water on clay, or hard-pan, and no water on sand, gravel, or sandy loam.

One fact we want to bear in mind, and that is, that any amount of ramming will only affect a comparatively thin layer.

Some years ago, we had a water pipe laid in a main street, which we intended soon to repave. The back-fill was made with no ramming ; a little water was run on top, under the impression that it was puddling. The trench was filled to the surface of the pavement, and crowned a little in the middle. The heavy traffic of the street was turned over this for several months, until the surface was apparently as hard as the pavement itself, the heaviest wheels making no impression on it. We then removed the top twelve inches of this trench, put in the ordinary seven inch gravel bed, and laid on granite blocks in the best possible manner. With the first rain, our pavement over the trench settled, and it continued settling for some months, with each rain and had then to be entirely relaid. In this case the surface was thoroughly rammed, but the effect was felt only for a depth of a few inches. When the surface was removed, and the blocks substituted, the water easily found its way through the joints into the trench, and this was gradually puddled.

The same is true with rolling a road. The heaviest steam roller cannot compact stone that is more than four or five inches in depth. Any great depth may apparently be settled, but breaking up will reveal the fact that all stones from three to five inches below the surface are as loose as when they were

placed there. We must roll a road in thin layers, to do any good. We must likewise ram a trench in thin layers, in order to insure it against settling.

In these days, when extraordinary measures are being taken to improve the roads of our country, we cannot afford to hang back and refuse to perform our share of the work. We have no right to look solely at our own particular part of the work, and leave the rest to some one else. The additional cost of good work in this direction is but a small percentage of the whole, and if we but add it to our original estimate, it will be but a small loss to us, while it will be an inestimable gain to the traveling public.

DISCUSSION.

Mr. Fuller. I have been very much interested in this paper and I heartily agree with what Mr. McClintock says. I have found it very difficult in my experience to get contractors to put the trench back in the shape we all desire to have it done, and I think perhaps one reason is that the price which is paid for doing contract work has been brought down to such a low figure that they cannot afford to do it. I do not believe that when a man gets from 20 to 25 cents a foot for laying 6-inch pipe he can so put back the material that has been excavated as to make a perfectly smooth, hard, flush surface. At one of our meetings some time ago a suggestion was made that work might be bid on in two ways, that is, there might be a price for putting back the material in the ordinary way, rounding it up and doing a certain amount of ramming, and also a price for ramming it so it will be flush and even with the surface. Then the parties having the work done could take their choice, and if they desire to have the work done the better way they could have it so done by paying for it. But I think that where a town is putting in, in one season, ten or twelve miles of water pipe, and they have none too much money to spend, it is pretty difficult to get the work done as you would like to have it, and the roads have to be left a little rough, and the next year smoothed off and finished up. I do not think that with a gang of Italians and the contractor driving them and hurrying along the work as fast as he can, which, of course, he is liable to do in spite of all you say to him, you can get the material put back in 3-inch layers and carefully rammed, so that when the work is done you will not know where the water trench had been dug.

Mr. Nevons. I have never in my experience seen water pipes laid where you couldn't find the ditch. Our method of filling is to throw in about a foot loose, and then fill the ditch about half full of water, and then throw in the dirt and break it all up, and we don't have any trouble at all. Of course we ram the top. We very seldom have to cart much of anything away, and I have known instances where we have had to cart material to help fill up the trench. In laying about eight miles of 30-inch main, a large proportion of which was laid through the streets of Waltham, and we also went through the main avenue in the cemetery, we used water whenever we could get it, and left our trenches so that we have never had to go back and put a shovelful on them since. The authorities commended us, and I think my friend the water superintendent in Waltham will bear me out when I say that we left

their streets in better shape than we found them. I think one of the most important things connected with water works construction is to leave the streets in good shape, and if we don't do it in our city we have the superintendent or the Mayor or somebody after us pretty quick, and we think we might as well do it as to have anybody else. I always want to use water if I can get it.

Mr. Decker. I have laid probably several hundred miles of pipe, and I have learned one thing, and that is that the hand of man never can place earth back as Nature puts it. I have found in my experience that with certain classes of soil I can get all the earth back and have to get dirt from somewhere else to fill up my ditch, while in another class of soil I can't begin to get all the dirt in. Like my brother Nevons, of Cambridge, I believe in the use of water. I find I can settle a ditch better by using water than I can in any other way, and I get a ditch that will give better satisfaction. I know some three or four years ago out in Kansas where the soil is peculiar, I don't know whether there is any such anywhere else on earth, I laid a 12-inch pipe, filled my ditch, flushed it in, and I lacked about six inches from the surface. With a four feet and a half ditch there we had to get about six inches to cover. I had never heard of its settling, and I don't think it has settled any.

Mr. D. W. French. I believe in the use of water, and use it whenever there is an opportunity. When it is impossible to obtain it I have had trouble on account of settling.

TOPICAL DISCUSSION.

[June 15, 1893.]

"DETAILS OF PIPE CASTINGS AND COATING."

MR. BRACKETT. Mr. President and gentlemen: Having been requested to open this discussion I have prepared a short paper upon one branch of the topic, viz : "Uniformity in the design for special castings."

In the specifications for water pipes the thickness and weight are generally carefully prescribed, and variations of more than from 3 to 4 per cent. from the weights called for are not allowed.

Special castings, however, are generally furnished of such patterns as the contractor may have in stock whether they be large or small, thick or thin, and as they are furnished by the pound the tendency is to have them both large and thick.

Even in cases where the castings are made from drawings furnished by the engineer or superintendent, there is a great difference in the weight of the castings furnished by different foundries from the same drawing.

As special castings cost about double the price per pound of the straight pipe, they should be made of as compact forms as is consistent with their convenient use, also taking into consideration the question of their influence upon the flow of the water in the mains. The frictional head lost in a branch is, under most circumstances, but a very small fraction of the loss in the straight pipes but under some circumstances, such as the branches supplying hydrants, elevators and motors, the difference in the discharge of a branch constructed so as to give an easy flow and one of the opposite form would be appreciable.

This is well illustrated by the sections of two branches, both made from the same drawing but cast at different foundries. In one case there is a smooth, well rounded approach to the branch, while in the other the opening is contracted, rough and nearly square edged.

Another point which appears to me to be worthy of consideration is the advantage of having special castings of uniform pattern. Under the present system the branches of the same size are of varying dimensions and the curves of different radii and curvature.

The pipe founders are often required to furnish castings of special design, causing delay and expense on account of patterns which must be made, when the standard forms would be equally serviceable if it were known that they could be furnished by the different foundries.

These preliminary remarks will explain my motive in presenting for your consideration and use the following designs for special castings. They are the standards adopted by the Boston water department and the principal foundries furnishing pipe to New England are already supplied with many of the patterns.

The dimensions of the bells and spigots, shown on Sheet No. 1 are applicable to all of the special castings.*

The general dimensions of the different patterns are given on the following sheets. The thickness of the castings, unless otherwise specified, agrees with the standard for pipe of the same internal diameter.

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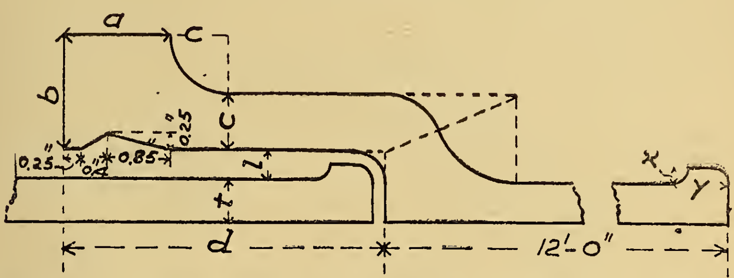
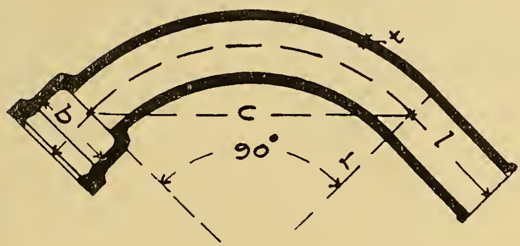
*See also Vol. III, p. 8.

PIPES.



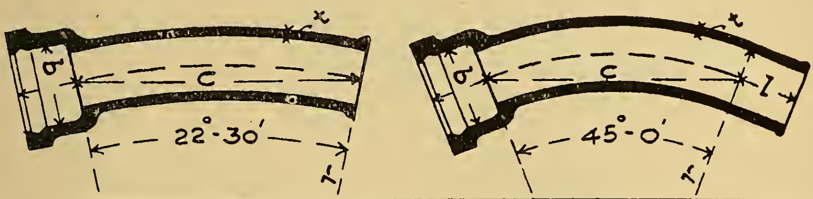
Diam. in Inches.	Class.	Dimensions in Inches.								Weight.
		a	b	c	d	t	l	x	y	
3	B	1.50	1.20	0.60	4.0	0.40	0.40	0.20	0.60	180
4	B	1.50	1.30	0.65	4.0	0.45	0.40	0.20	0.60	260
6	B	1.50	1.40	0.70	4.0	0.50	0.40	0.20	0.60	420
8	B	1.50	1.50	0.75	4.0	0.55	0.40	0.20	0.60	600
10	B	1.50	1.60	0.80	4.5	0.60	0.40	0.20	0.80	815
12	A	1.50	1.60	0.80	4.5	0.58	0.40	0.20	0.80	935
12	B	1.50	1.70	0.85	4.5	0.65	0.40	0.20	0.80	1050
16	A	1.75	1.70	0.85	5.0	0.66	0.50	0.25	0.85	1415
16	B	1.75	1.90	0.95	5.0	0.75	0.50	0.25	0.85	1615
20	A	1.75	1.90	0.95	5.0	0.73	0.50	0.25	0.85	1950
20	B	1.75	1.90	0.95	5.0	0.85	0.50	0.25	0.85	2250
24	A	2.00	2.10	1.05	5.0	0.81	0.50	0.25	0.85	2590
24	B	2.00	2.10	1.05	5.0	0.94	0.50	0.25	0.85	2985
30	A	2.00	2.30	1.15	5.0	0.93	0.50	0.25	0.85	3690
30	B	2.00	2.30	1.15	5.0	1.10	0.50	0.25	0.85	4335
36	A	2.00	2.50	1.25	5.0	1.04	0.50	0.25	0.85	4930
36	B	2.00	2.50	1.25	5.0	1.25	0.50	0.25	0.85	5880
40	A	2.00	2.70	1.35	5.0	1.12	0.50	0.25	0.85	5900
40	B	2.00	2.70	1.35	5.0	1.35	0.50	0.25	0.85	7050
48		2.00	2.70	1.35	4.0	1.00	0.50	0.25	0.85	6275
48	A	2.00	3.00	1.50	5.5	1.25	0.50	0.25	0.85	7920
60		2.25	3.40	1.70	6.0	1.375	0.50	0.25	0.85	10960

ONE QUARTER CURVES.



Diam. in Inches.	Class.	Dimensions in Inches.					Weight.	
		b	t	r	c	l		
3	B	4.6	0.40	16	22.6	8	55	
4	B	5.8	0.45	16	22.6	8	80	
6	B	7.8	0.50	16	22.6	8	125	
6	B	7.8	0.50	24	34.0	6	150	
8	B	9.9	0.55	16	22.6	10	185	
8	B	9.9	0.55	24	34.0	6	215	
10	B	12.0	0.60	16	22.6	12	260	
10	B	12.0	0.60	24	34.0	6	295	
12	B	14.1	0.65	16	22.6	12	330	
12	B	14.1	0.65	24	34.0	6	375	
16	B	18.5	0.75	24	34.0	12	645	
20	B	22.7	0.85	24	34.0	12	880	
24	B	26.9	0.94	30	42.4	12	1355	

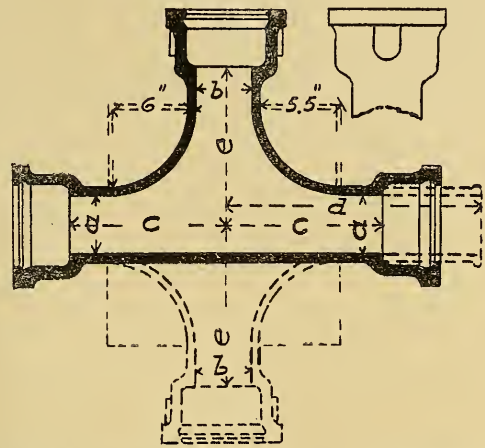
1/16 CURVES. 1/8 CURVES.



Diameter of Pipe.	Class.	b	t	1/16 Curves. r	1/16 Curves. c	1/16 Curves. Weight.	1/8 Curves. r	1/8 Curves. c	1/8 Curves. l	Weight.
3	B	4.6	0.40	48	18.7	40	24	18.4	4	45
4	B	5.8	0.45	48	18.7	55	24	18.4	4	65
6	B	7.8	0.50	48	18.7	85	24	18.4	4	95
8	B	9.9	0.55	48	18.7	120	24	18.4	4	135
10	B	12.0	0.60	48	18.7	165	24	18.4	4	185
10	B	12.0	0.60	120	46.8	310	60	45.9	—	310
12	B	14.1	0.65	48	18.7	210	24	18.4	4	235
12	B	14.1	0.65	120	46.8	400	60	45.9	—	400
16	B	18.5	0.75	120	46.8	620	60	45.9	—	620
20	B	22.7	0.85	120	46.8	845	60	45.9	—	845
24	B	26.9	0.94	120	46.8	1125	60	45.9	—	1125
30	A	33.2	0.93	120	46.8	1405	60	45.9	—	1405
30	B	33.2	1.10	120	46.8	1620	60	45.9	—	1620
36	A	39.1	1.04	180	70.2	2615	90	68.9	—	2615
40	A	43.25	1.12	180	70.2	3130	90	68.9	—	3130
48	A	51.5	1.25	180	70.2	4215	90	68.9	—	4215

Dimensions in Inches.

BRANCHES.



Dimensions in Inches.					Weight.			
					Three Way Branch		Four Way Branches	
a	b	c	d	e	Two Bells.	Three Bells	Three Bells	Four Bells
4	3	10.5	22.5	11				
4	4	11.0	23.0	11	125	125		
6	3	10.5	22.5	12	160	160		
6	4	11.0	23.0	12	165	165		
6	6	12.0	24.0	12	205	205		
8	3	10.5	22.5	13	200	200		
8	4	11.0	23.0	13	220	220		
8	6	12.0	24.0	13	250	250		
8	8	13.0	25.0	13	290	290		
10	4	11.0	23.0	14	290	290		
10	6	12.0	24.0	14	325	325		
10	8	13.0	25.0	14	360	360		

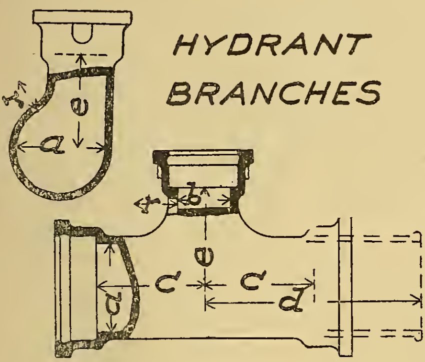
BRANCHES.

Dimensions in Inches.					Weight.			
					Three Way Branches		Four Way Branches.	
a	b	c	d	e	Two Bells.	Three Bells	Three Bells	Four Bells
10	10	14	26	14	400	400		
12	4	11	23	15	360	360		
12	6	12	24	15	390	390		
12	8	13	25	15	430	430		
12	10	14	26	15	480	480		
12	12	15	27	15	520	520		
16	4	11	23	17	550	550		
16	6	12	24	17	575	580		
16	8	13	25	17	625	630		
16	10	14	26	17				
16	12	15	27	17				
16	16	17	29	17				
20	6	12	24	19				
20	8	13	25	19				
20	10	14	26	19				
20	12	15	27	19				
20	16	17	29	19				
20	20	19	31	19				
24	6	12	24	21				
24	8	13	25	21				
24	10	14	26	21				
24	12	15	27	21				
24	16	17	29	21				
24	20	19	31	21				
24	24	21	33	21				
30	12	15	27	24				
30	16	17	29	24				
30	20	19	34	24				
30	24	21	36	24				
30	30	24	41	24				
36	12	15	27	27				

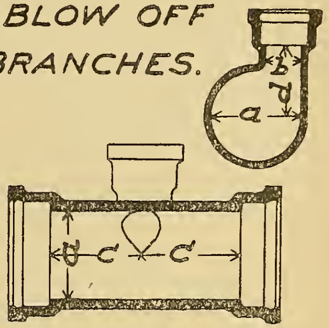
BRANCHES.

Dimensions in Inches.					Weight.			
					Three Way Branches		Four Way Branches.	
a	b	c	d	e	Two Bells.	Three Bells	Three Bells.	Four Bells
36	16	17	29	27				
36	20	19	34	27				
36	24	21	36	27				
36	30	24	41	27				
36	36	27	44	27				
40	12	15	27	29				
40	16	17	29	29				
40	20	19	34	29				
40	24	21	36	29				
40	30	24	41	29				
40	36	27	44	29				
40	40	29	46	29				
48	16	17	29	33				
48	20	19	34	33				
48	24	21	36	33				
48	30	24	41	33				
48	36	27	44	33				
48	40	29	46	33				
48	48	33	50	33				

HYDRANT BRANCHES



BLOW OFF BRANCHES.



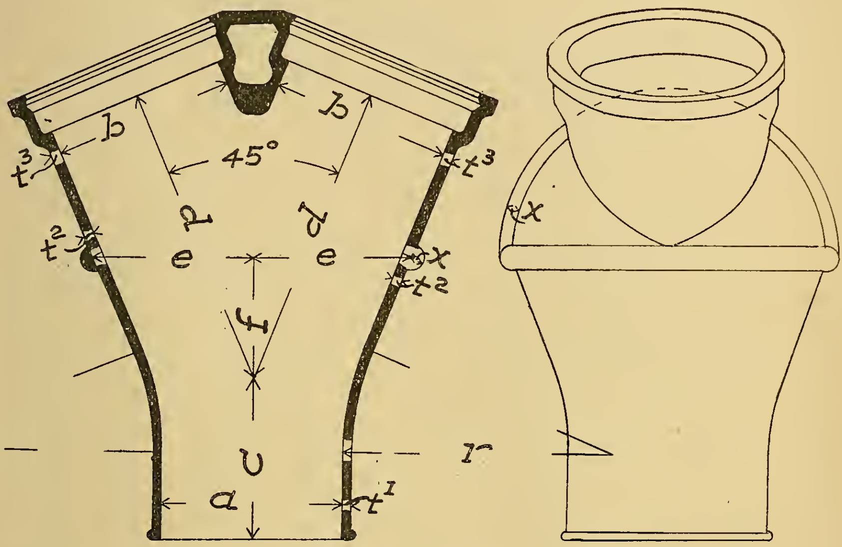
HYDRANT BRANCHES.

DIMENSIONS IN INCHES.						WEIGHT.
a	b	c	d	e	r	
10	6	12	24	11	5	
12	6	12	24	12	5	
16	6	12	24	15	5	

BLOW OFF BRANCHES.

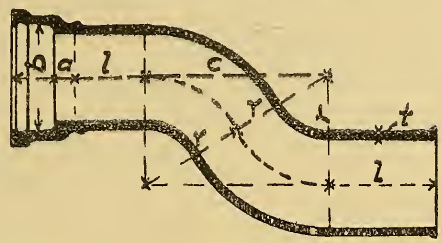
DIMENSIONS IN IN'S.				WEIGHT.
a	b	c	d	
8	4	10	7	
10	4	10	8	
12	4	10	10	
16	4	10	12	
20	6	12	14	
24	6	12	16	
30	12	13	20.5	
36	12	13	23.5	
40	12	13	25.5	
48	16	24	29.5	

Y BRANCHES.



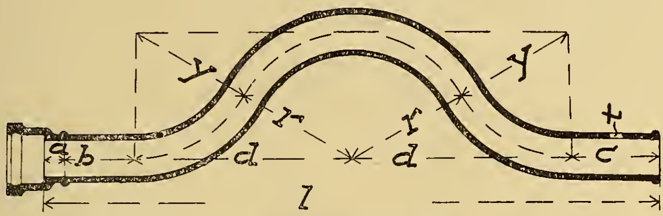
DIMENSIONS IN INCHES.											WEIGHT.
a	b	c	d	e	f	r	t^1	t^2	t^3	x	
20	20	18	34	17.6	13.5	30	0.85	1.10	0.85	1.25	
24	24	18	38	20.6	15.25	30	0.94	1.20	0.94	1.25	
30	24	12	38	20.6	15.25	30	1.10	1.20	0.94	1.25	
30	30	18	48	25.3	18.0	30	1.10	1.40	1.10	1.25	
36	36	18	54	29.8	21.0	24	1.04	1.50	1.04	1.50	
40	40	18	60	33.3	24.0	24	1.12	1.60	1.12	1.50	
48	48	18	68.5	39.5	28.0	24	1.25	1.75	1.25	1.50	

OFFSETS.



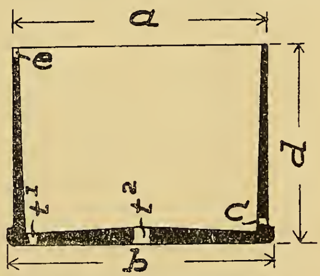
Diam. of Pipe.	Dimensions in Inches.						Weight.	
	a	b	c	l	r	t		
4	2	5.8	13.86	10	8	0.45	90	
6	2	7.8	13.86	10	8	0.50	140	
6	2	7.8	24.25	10	14	0.50	170	
8	2	9.9	17.32	10	10	0.55	215	
8	2	9.9	25.98	10	15	0.55	255	
10	2	12.0	20.78	10	12	0.60	310	
10	2	12.0	—	10	—	0.60	—	
12	2	14.1	24.25	10	14	0.65	430	
12	2	14.1	—	10	—	0.65	—	

SIPHON PIPES.



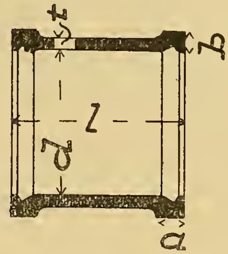
DIAM. OF PIPE.	DIMENSIONS IN INCHES.								WEIGHT.	
	a	b	c	d	r	y	t	l		
4	2	8	8	24.25	14	14	0.45	66.5	150	
6	2	8	8	27.70	16	16	0.50	73.4	260	
8	2	8	8	30.00	18	16	0.55	78.0	400	
10	2	8	8	31.10	19	16	0.60	80.2	560	
12	2	8	8	32.25	20	16	0.65	82.5	740	

PLUGS.



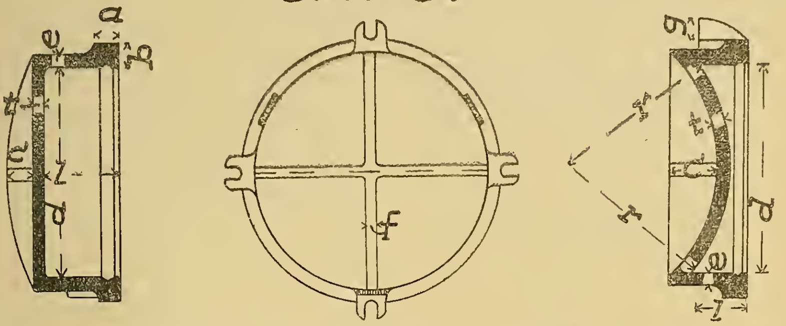
DIAM. OF PIPE.	DIMENSIONS IN INCHES.								WEIGHT.	
	a	b	c	d	e	t^1	t^2			
3	3.8	4.20	0.25	5.5	0.125	0.35	0.35		4	
4	4.9	5.30	0.25	5.5	0.125	0.35	0.35		6	
6	7.0	7.40	0.25	5.5	0.125	0.35	0.50		10	
8	8.10	8.50	0.25	5.5	0.125	0.40	0.50		13	
10	11.20	11.60	0.30	6.0	0.20	0.50	0.60		28	
12	13.20	13.60	0.30	6.0	0.20	0.50	0.75		38	
16										

SLEEVES.



DIAM. OF PIPE.	DIMENSIONS IN INCHES.						
	a	b	d	l	t	WEIGHT.	
3	1.5	1.2	4.6	10	0.6	35	
4	1.5	1.3	5.8	10	0.65	45	
6	1.5	1.4	8.0	10	0.7	67	
8	1.5	1.5	10.1	12	0.75	100	
10	1.5	1.6	12.25	12	0.8	130	
12	1.5	1.7	14.35	14	0.85	185	
16	1.75	1.8	18.75	15	0.9	275	
20	1.75	1.9	23.0	15	0.95	350	
24	2.0	2.1	27.2	15	1.05	470	
30	2.0	2.3	33.6	15	1.15	640	
36	2.0	2.5	39.6	15	1.25	820	
40	2.0	2.7	43.7	15	1.35	980	
40	2.0	2.7	43.7	20	1.35	1230	
48	2.0	3.0	52.0	15	1.50	1290	
48	2.0	3.0	52.0	20	1.50	1620	

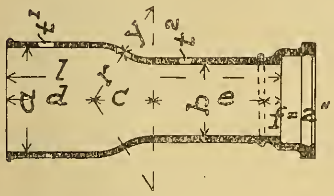
CAPS.



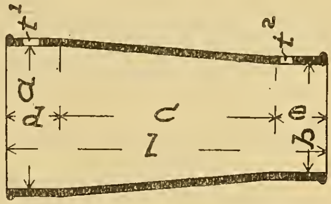
10" and 12" caps have two ribs.
16", 20", 24", 30" and 36" caps have three ribs.
40" and 48" caps have four ribs.

DIAM. OF PIPE.	DIMENSIONS IN INCHES.										WEIGHT.
	a	b	c	d	e	f	g	l	t	r	
3	1.5	1.20	—	4.6	0.60	—	—	3.75	0.50	—	18
4	1.5	1.30	—	5.8	0.65	—	—	3.75	0.60	—	25
6	1.5	1.40	—	8.0	0.70	—	—	3.75	0.65	—	40
8	1.5	1.50	—	10.1	0.75	—	—	5.	0.75	—	70
10	1.5	1.60	1.50	12.25	0.80	0.75	—	5.	0.75	—	95
12	1.5	1.70	1.75	14.35	0.85	0.75	—	5.	0.75	—	125
16	1.75	1.90	2.00	18.75	0.95	0.75	—	5.	1.0	—	210
20	2.0	1.90	2.50	22.7	0.95	1.0	—	5.	1.0	—	275
24	2.0	2.1	3.00	26.9	1.05	1.0	2.5	5.	1.05	—	440
30	2.0	2.3	2.85	33.2	1.15	1.0	2.5	5.	1.15	48	640
36	2.0	2.5	4.00	39.1	1.25	1.25	2.5	5.	1.25	48	920
40	2.0	2.7	4.00	43.25	1.35	1.50	2.5	5.	1.50	54	1220
48	2.0	3.0	4.00	51.5	1.50	1.50	2.5	5.5	1.75	96	2050

REDUCERS.



No. 1.



No. 2.

DIMENSIONS IN INCHES.												WEIGHT.
No.	a	b	c	d	e	r	y	l	t^1	t^2	CLASS	
1	4	3	2	7	9	2	2	20	0.45	0.40	B	55
1	6	4	3.3	7	10.7	3	3	23	0.50	0.45	B	75
1	8	6	3.8	7	10.2	4	4	23	0.55	0.50	B	110
1	10	6	6.0	10	12	5	5	30	0.60	0.50	B	155
1	10	8	4.6	10	12	5	6	28.6	0.60	0.55	B	180
1	12	6	8.0	10	12	6	6	32	0.65	0.50	B	185
1	12	8	6.6	10	12	6	6	30.6	0.65	0.55	B	210
1	12	10	4.8	10	12	6	6	28.8	0.65	0.60	B	240
2	16	10	20	8	8	—	—	36	0.75	0.60	B	285
2	16	12	20	8	8	—	—	36	0.75	0.65	B	310
2	20	12	26	8	8	—	—	42	0.85	0.65	B	450
2	20	16	26	8	8	—	—	42	0.85	0.75	B	530
2	24	16	26	8	8	—	—	42	0.94	0.75	B	630
2	24	20	26	8	8	—	—	42	0.94	0.85	B	720
2	30	20	26	8	8	—	—	42	1.10	0.85	B	900
2	30	24	26	8	8	—	—	42	1.10	0.94	B	1000
2	36	30	32	8	8	—	—	48	1.15	1.10	B	1530
2	36	30	32	8	8	—	—	48	1.04	0.93	A	1340
2	40	30	32	8	8	—	—	48	1.12	0.93	A	1480
2	40	36	32	8	8	—	—	48	1.12	1.04	A	1675
2	48	36	32	8	8	—	—	48	1.25	1.04	A	1980
2	48	40	32	8	8	—	—	48	1.25	1.12	A	2130

The designs are not claimed to be better than any others which may have been or can be made, but they are thought to be of as compact form and light weight as it is advisable to adopt.

The reducers and offsets have a bead cast back of the bell so that the bell can be cut off leaving a bead on the end of the casting. This plan has been adopted to avoid a multiplicity of patterns, but if desired the castings could be ordered without bells.

The design for Y branches is one which has been used in Boston for the past twenty years with the best of results. Y branches are apt to be deficient in strength, but I have never known of the failure of one of this design.

As to the limit of variation from the standard weights which should be allowed, it seems to me that a variation of 4 or 5 per cent. should be the requirement of our specifications.

There is another point I wish briefly to touch upon, a subject I spoke of a year ago, and that is the casting of a pipe bell up or bell down. At that time there seemed to be an opinion among a number of the members that it was a point of very little importance, and one gentleman advanced the idea that it was the province of the engineer to specify the kind of pipe wanted, and the province of the founder to make it in any way he saw fit. I only wish now to quote from a letter the opinion of Mr. George W. Whitman, who has been an inspector of pipes for many years, and whose opinion I consider of great value. In reply to an inquiry in regard to the question, he answers as follows: "I was under the impression that the bell-up or bell-down question had been finally settled. Of course, founders having no fixtures for casting pipes head down will argue that head up is just as good. But I have noticed that as soon as they have fixtures for head down work they generally acknowledge that that gives a much more solid and clean head, overcomes the liability of shrinkage cracks in the neck, gives a uniform size and depth of socket, and is in every way the best and easiest way to cast pipe."

Mr. Billings. I am moved to say this much in reply to the remarks of my friend Brackett, and that is that the letter which he has read from Mr. Whitman, as I interpret it bears out to some degree the position which I took a year ago, namely, that it is the pipe founders themselves who have settled the point as to what is the best method of casting pipe. I said at that time, I think, that all pipe founders agree, all founders of any sort of iron castings, that the better iron is found in the bottom of the blow, but I also said it was a subject for the founders to settle, and if they finally agreed they could get the pipe which the engineer wanted by casting it bell down, that was the way to do it, and that they were the ones to say whether it should be bell down or bell up. And Mr. Whitman appears to say that the founders have settled it for us by deciding that they can cast it bell down, and do so.

Mr. Brackett. It seems to me that with pipe contractors, as with contractors in general, there is likely to be a difference of opinion as to the way work should be done; and while one man may be ready to do it in the best way, another one for personal reasons may prefer to do it in some other way which may be cheaper but may not give the best results.

Mr. Noyes. This question is one which has been of great interest to me for a number of years. It has been brought very largely to my attention from the claim of pipe founders, especially, as Mr. Brackett suggests, when they are not specially rigged for casting their pipe bell down, that the pipe comes out just as well exactly, and perhaps it is a little better, by being cast bell end up, rather than bell down. Wishing to be entirely conservative in my judgment in all these things, and placing confidence in the experience of the founders, I have endeavored to look into the matter very carefully; and from all the evidence I can get, either from personal observation or from conversation with inspectors who have given special attention to the question of the relative quality of pipe cast one way as against that cast the other way, I find by my own experience and observation, and it has been stated almost universally by the inspectors, that the better average pipe is obtained with the bells cast down; that with the bells cast up the area of the opening is less in proportion to the whole than it is with the spigot up; that the dirt or dross does not get out of the iron, and that a larger percentage of the bells, that is, a larger percentage of the pipe, are defective in the bells cast in that way.

During the past year, or within the last eighteen months, the matter has been under very considerable discussion, and the strongest kind of pressure has been brought by the founders to induce the engineer to admit the pipe cast bell up.

Mr. Allen. I want to say that I think this matter of having standard special castings is a most excellent idea. It seems to me that there is nothing to be said against it. I should hope that it might be brought about that there would be a standard fixed, so that when ever we wanted a special casting of any form we could simply send to the founder and state what we want and have it sent, without special plans. I think very likely the society could have a great influence in bringing that about if they should take it upon their hands to do so, and I should think it had better be done.

Mr. Fuller. My experience has been that pipes are more often cracked at the spigot end than at the bell end. I suppose, if it were necessary that there should be cracks at all, they had better be at that end. But it seems to me that there cannot be any doubt that it is better to cast the pipes with the bell ends down, and I judge from what I hear that that is becoming the uniform custom. I think that the pipe that we get from the manufacturers nowadays is certainly of good quality, and if the trouble of uneven thickness could be avoided, it seems to me that there would not be much left to be desired in the matter of cast-iron pipe.

A DESCRIPTION OF THE HYDRAULIC LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY

PROF. DWIGHT PORTER.

[Read and Illustrated by Stereopticon, June 14th, 1893.]

This laboratory has been arranged and equipped upon an extensive scale for experimental researches and practical tests in hydraulics. The apparatus is used by the students of nearly all the engineering courses in regular laboratory exercises, during which they work in sections no larger than strictly necessary for conducting the particular experiment in hand. Such work is designed to give the students a practical demonstration of laws with which they have become familiar in a theoretical way only, to acquaint them with the appearance and behavior of certain standard forms of apparatus, and to teach them the methods and precautions commonly necessary in hydraulic experiments. The time allotted to any one variety of work is what seems sufficient fairly to attain the above ends, and no more, it not being proposed in class exercises to make the young men adepts, nor in general to achieve results in those exercises of especial scientific importance. In connection with thesis work, or the studies of post-graduate students, special apparatus is every year devised and installed, suited to original investigations and to the securing of results of permanent interest and value.

The space devoted to the hydraulic laboratory covers about 30 x 50 feet on each of the two lower floors of the engineering building. The general arrangement of pipes and apparatus on the second floor of the laboratory is shown by the plan (Figure 1), and the view (Figure 2). The primary source of water-supply is the city main, but it is rarely that draught is made directly upon this during an experiment, water being directly supplied from pumps, which in turn draw from a large receiving-pit sunk below the basement floor, the discharge from all experiments finding its way to the pit and thus being used over and over. Several pumps are in use—steam, rotary and centrifugal—supplying the different apparatus. In order to secure a more constant pressure than that from the pumps, for certain kinds of experiments, a ten-inch stand-pipe, shown in plan in Figure 1, eighty feet high, has been built, reaching to the top of the building. The supply to this from the pumps may be so regulated by valves and over-flows, conveniently arranged on each floor, that the head shall be kept at any desired point during an experiment, with a fluctuation of scarcely a hundredth of a foot. Many of the pieces of apparatus have been so arranged that they can be run at will under pressure either from the standpipe or directly from the pumps.

An important feature of the plant is a closed steel tank, five feet in diameter

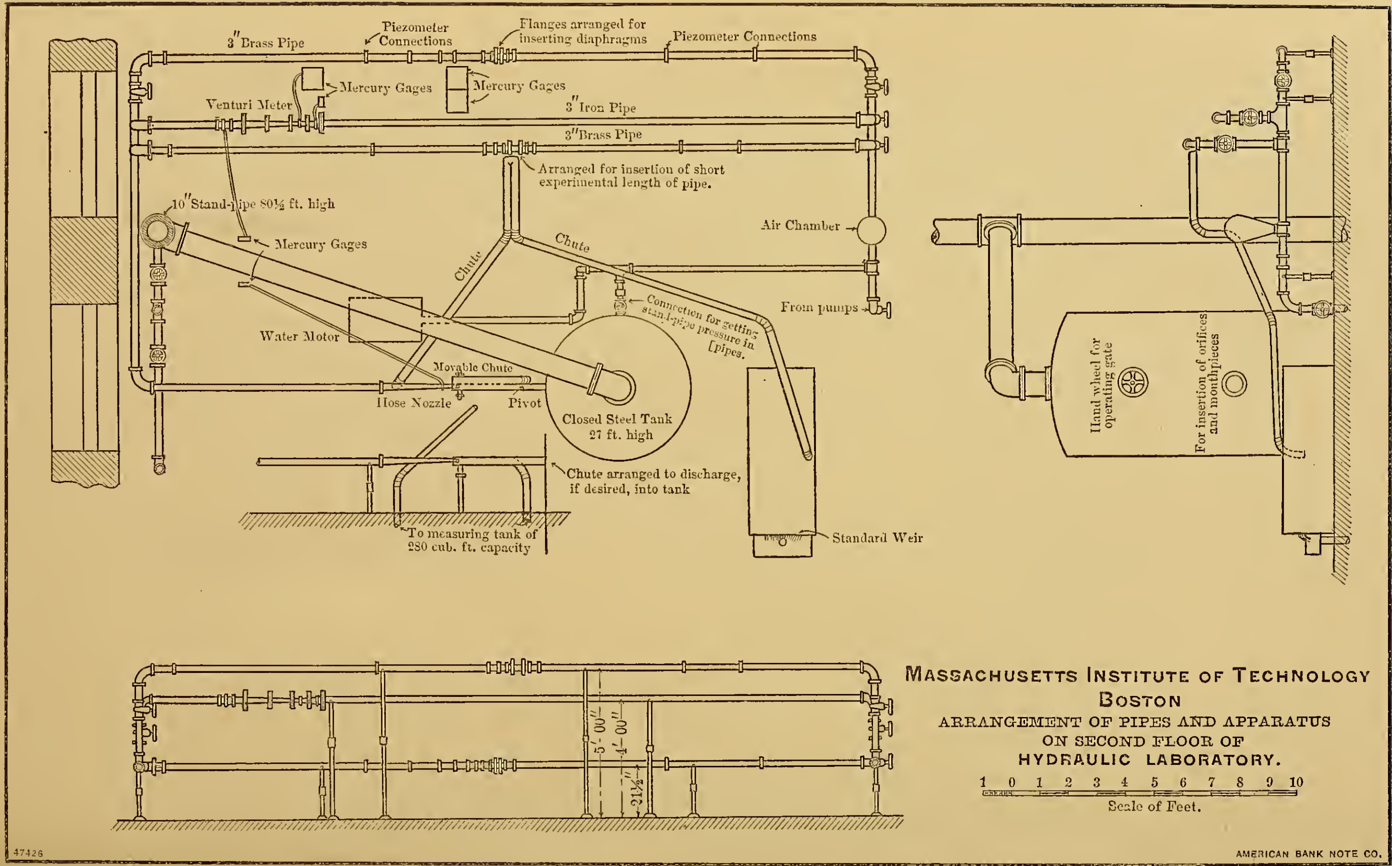


Fig. 1. Pipes and Apparatus on Second Floor of Hydraulic Laboratory.

and twenty-seven feet high (Figures 1, 2 and 4), extending from the basement floor upward through two stories. It is connected at top and at bottom with the stand-pipe previously mentioned, and at four points on each floor is arranged for the insertion of orifices, free or submerged, mouthpieces and other fittings, and for connections with motors and experimental pipes. It is fitted with hydraulic gates so planned that an orifice, for example, may be quickly exchanged for another without the necessity of drawing down the water in the tank.

For certain experiments on the flow of water through pipes, three lines of three-inch pipe (Figures 1 and 2) have been erected. One of these is of iron, with a Venturi meter, shown on the right of the foreground of Figure 2, inserted in its course; the other two are of brass, very carefully made, with piezometer connections of approved form at sundry points. One of the brass pipes is arranged for the insertion of diaphragms with orifices of various sizes; and the other, for the insertion of short experimental pieces of pipe provided with side orifices, branches, or other devices. The discharge from the various pipe-lines passes finally through a hose-nozzle, with pressure-gauge connection to be used in determining the co-efficient of discharge. The nozzle discharges (Figure 1) into a movable double-chute, through one branch of which the flow may be wasted until it is desired to begin an experiment, when the other branch may instantly be thrown into the path of the jet, and the water directed through the floor into a measuring-tank beneath.

For delicate observations upon the velocity at any given point in flowing water, the laboratory contains three different instruments (Figure 3) embodying the principle of the Pitot tube. Two of these, for use, respectively, in jets from nozzles and in streams flowing under pressure through pipes, are the property of Mr. John R. Freeman, by whom they have kindly been placed at the command of the Institute. The third, for jets from standard orifices, has been designed especially to use on the large tank, which has been described, and one in use is shown by Figure 4. In each case, the pressure of the flowing water due to its velocity is transmitted through a minute orifice and a connecting tube to a mercury gauge, the reading of which indicates the velocity at the tip of the tube. A simple attachment to the last-mentioned of these devices has permitted measuring the shape of the jet and the size of the contracted vein with the greatest nicety.

For measuring the quantity of water discharged during experiments, the common method employed is that of weighing, the temperature of the water being at the same time observed. Thus, in determining the co-efficient of discharge of standard orifices, the flow from the orifice passes into a large cask, with ample discharge-pipe and quick-acting valve at the bottom, and thence into another and similar cask underneath, resting directly upon scales. The upper cask serves for temporary storage while the contents of the lower one are being weighed and discharged. By this means, with casks of moderate size, it is not difficult to weigh continuously at the rate of 40,000 or 50,000 pounds of water per hour. Again, the discharge from experiments on the

second floor may be diverted through chutes to any one of several measuring devices on the floor below. One of the most important of these is a cylindrical steel tank, six feet in diameter and ten feet high, capable of holding some 280 cubic feet of water. This tank is conveniently placed for drawing off and weighing the contents, and is by this means calibrated. In order to determine the quantity discharged into the tank in any experiment, it is then necessary only to read a glass-gauge attached to the tank and provided with sliding sight and vernier. For more indirect determinations of quantities of water, the laboratory contains a number of weirs of different lengths, up to four feet, a calibrated orifice tank, Venturi and other water-meters, nozzles and standard orifices.

The pieces of apparatus which have been mentioned will suggest to the mind a great variety of experimental work to which they are suited, and to much of which they have actually been applied. The laboratory further contains a Pelton water-motor, a small Swain turbine, a Douglas hydraulic ram and a variety of dynamometers, mercury-gauges, piezometer fittings, etc. Figure 5 is a view of a Swain turbine being tested by students. There have also been placed in the laboratory a large number of finely-constructed orifices and metal pieces of sundry descriptions, which were used many years ago by Uriah Boyden and James B. Francis in their famous experimental work at Lowell.

The laboratory has been designed with a view to extensive further developments, important advances in which are likely to be made every year. It has been steadily taxed to its utmost capacity, both for regular class exercises and for thesis work, and fully commends itself as a substantial aid in engineering education.

HYDRAULIC FIELD-WORK.

In connection with the laboratory, it seems not out of place to mention the course in Hydraulic Field-Work, which is similar in nature to work in the laboratory, but is on a larger scale. It consists in measuring the flow of some stream by means of current-meters and floats. The civil engineering department is equipped with Fteley, Ellis, and Ritchie-Haskell current-meters, and with tubes, Ellis sub-surface and other forms of floats. Hydraulic measurements constitute an important part of the summer-school work, and students not attending that school receive their practice in the early part of the fall term in the vicinity of Boston, exercises being arranged so that, for a time, one day of the week is entirely free for this work. For the term work, measurements have been made, at various times, of the flow of the Charles and Merrimac rivers, and of the hydraulic canals at Lowell and Lawrence; while at the summer-school the Connecticut, Delaware and Schoharie rivers have been gauged. These streams have given a range in volume from 50 to 8,000 or 10,000 cubic feet per second, and a great variety of conditions as regards width, depth, velocity of current, and methods of conducting the measurements. The observations made in the field are worked up in the drawing-room, diagrams being constructed for the cross-sections and velocity curves, and the computations being based upon them.

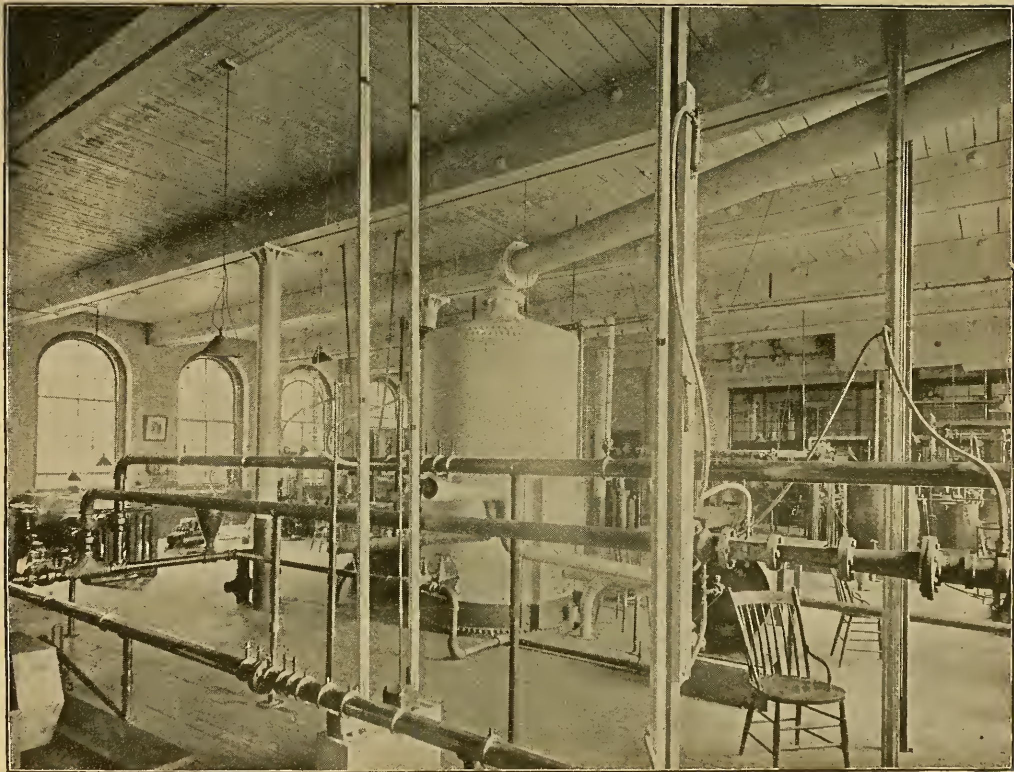


Fig 2. View of Second Floor of Hydraulic Laboratory.

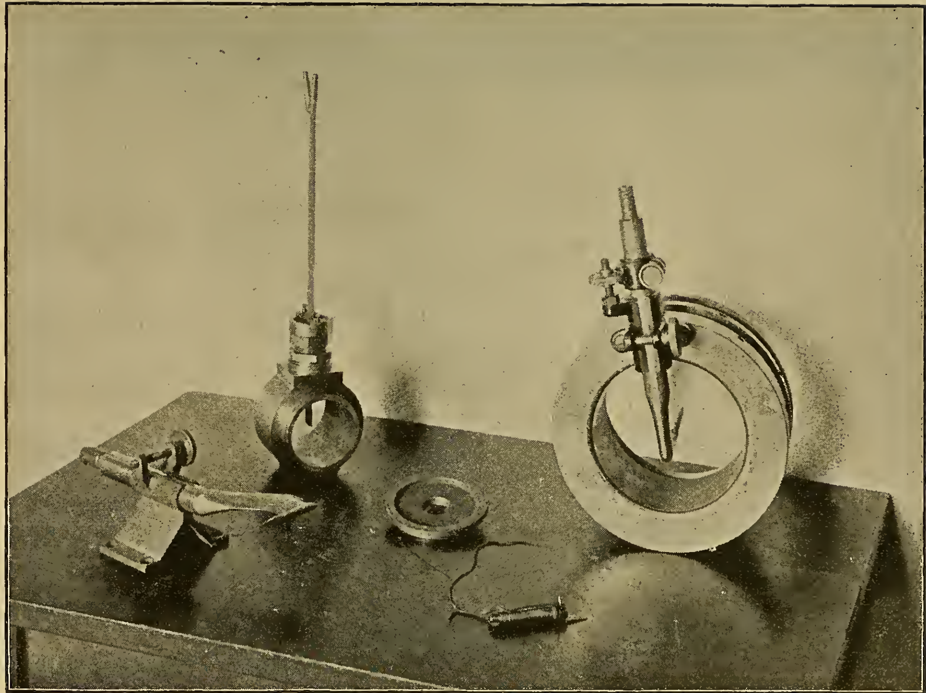


Fig. 3. Forms of Pitot Tubes Used in Experiments on the Velocity in Flowing Water.

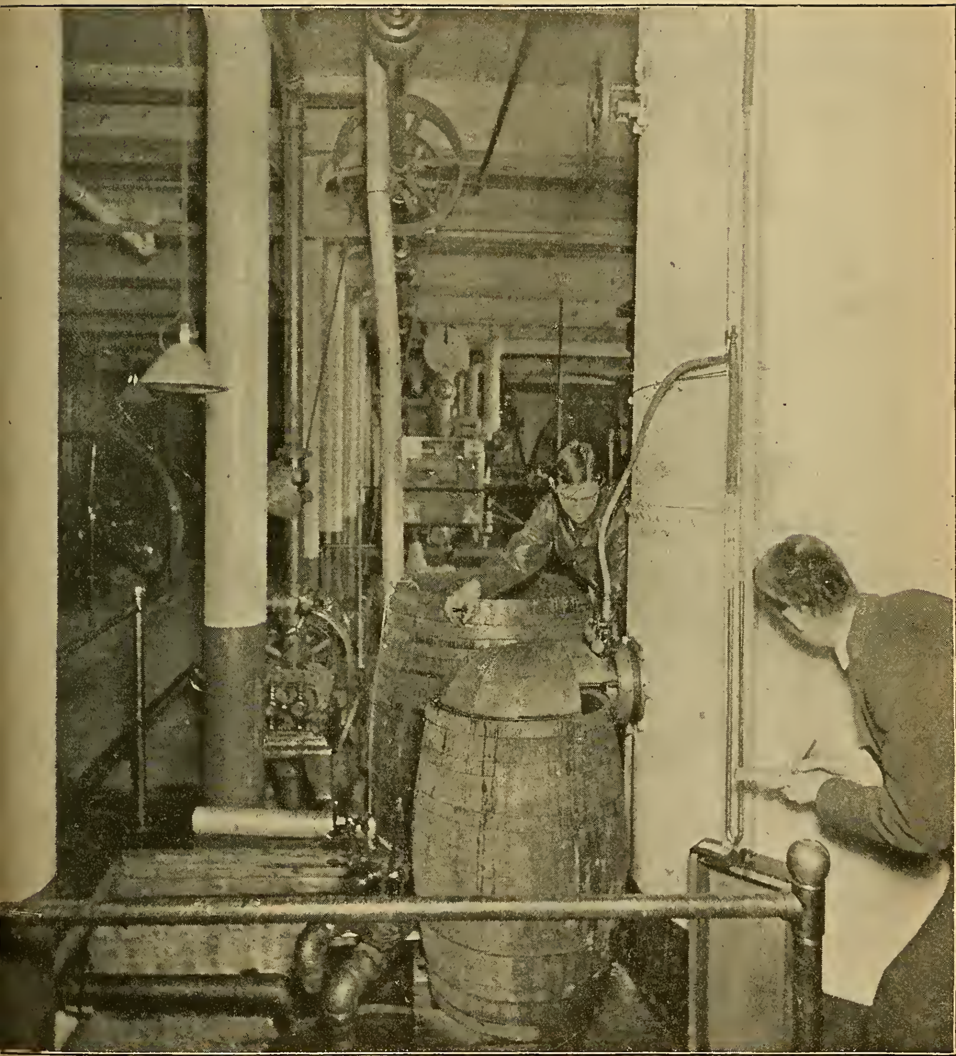


FIG. 4. Studying Variations in Velocity in a Jet from a Standard Orifice by Means of a Pitot Tube.

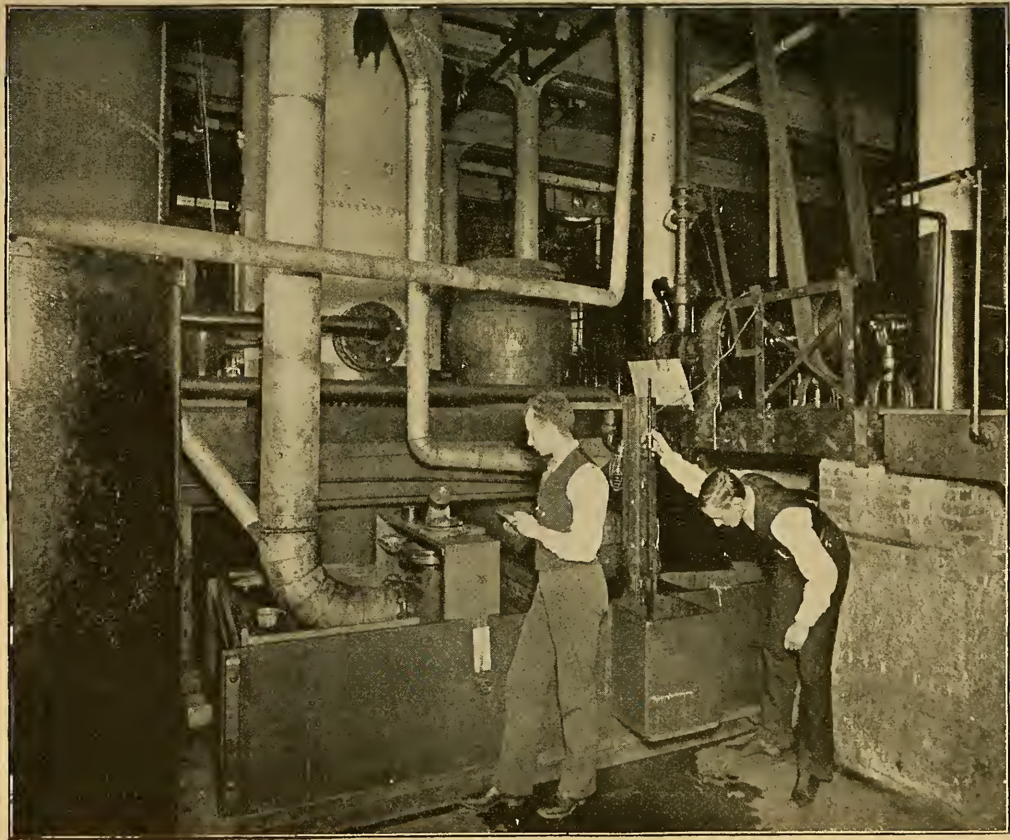


FIG. 5. Students Testing a Swain Turbine.

RECENT PRACTICE IN PUMPING ENGINES.

BY

F. W. Dean, Mechanical Engineer, Boston, Mass.

[Read and illustrated by Stereopticon, June, 15, 1893.]

The development of pumping engines is a subject of great fascination. It seems strange to us that the Cornish engine should have reached such a state of perfection before the middle of this century, as to give a duty of 120,000,000 ft. lbs. per 100 lbs. of coal, but there seems to be no doubt that this was accomplished in 1840 at Fowey Consols Mines in Cornwall, by an engine with a cylinder 80 in $\times$ $10\frac{1}{3}$ ft. and carrying a net pressure of 12.57 lbs. of steam per sq. in. This high rate of duty was brought about by using the steam expansively, by using steam jackets well protected, by an ingenious arrangement of valves which prevented the condenser temperature from extending to the steam side of the piston, adjacent cylinder heads and clearances, by compressing the steam to the initial pressure, by wire drawing and somewhat super-heating the working steam and causing the initial pressure and temperature to be considerably below those in the jacket, and thus almost wholly preventing condensation. The efficiency of the jacket was increased by the slowness of the return stroke of the steam piston, and by a pause of nearly a quarter of a minute between the completion of this stroke and the beginning of the steam stroke. The steam stroke was made with astonishing rapidity for such ponderous moving parts, amounting in cases to a rate of 500 feet a minute, and thus minimizing condensation.

The most economical performances of these engines occurred when they were new and under-worked. When the mines grew deeper and the steam worked less expansively, the duty diminished. The engine that once gave 120 millions duty, two years afterwards gave 77 millions.

The principle of expansion and the importance of diminishing condensation in steam cylinders were well understood in those days, the former having been thought out in 1769 and the steam-jacket invented in 1763, both by James Watt.

The average annual duty of Cornish engines in 1840 was about 55,000,000 ft. lbs.

Previous to 1873 the usual duty of pumping-engines in this country was about 60,000,000 ft. lbs. per 100 lbs. of coal, but in July, 1873, this time-honored record was broken by the so-called Morris engine at Lowell, Mass. This is a compound vertical engine of the Simpson type of 5,000,000 gals. capacity having both cylinders under one end of the beam and the pump and fly-wheel under the other. Steam enters the high-pressure cylinder from the boiler and at the completion of the stroke flows into the opposite end of the low-pressure cylinder, the steam flowing from one to the other during the whole stroke.

In July, 1873, a board consisting of Messrs. Hoadley, Francis and Worthen obtained a duty from this engine of 93,002,272 ft. lbs. per 100 lbs. of coal.

About this time the Worthington horizontal compound duplex pumping-engine was being introduced with great satisfaction and gave a duty of about 60,000,000 ft. lbs. per 100 lbs. of coal. The first engine of this type was built for the Charlestown, Mass., Water Works and was erected in 1864. A duplicate was there erected in 1866. The cylinders were 25 in. and 43 in. by 48 in. stroke. The pump-plungers were 22 in. in diameter, and the delivery-pipe 30 in. in diameter. The engines have been in service ever since, and are at work at present. This is a remarkable record, extending nearly 30 years.

A distinct impulse was given to high-class pumping-machinery by Mr. E. D. Leavitt, whose engine at Lynn was tested in Dec., 1873. This was an improvement on the Morris engine at Lowell in consequence of the pistons moving in opposite directions, and thus diminishing the length and volume of the passages between the cylinders. These features were accomplished by connecting the pistons to opposite ends of the beam, and thus permitting the high-pressure exhaust to pass to the nearest end of the low-pressure cylinder. The virtues of this arrangement were still farther brought out by inclining the cylinders so as to bring them as near together as possible.

The superiority of the Lynn over the Lowell engine did not end here, however. This engine had a type of steam-valve that gave a large port opening with small clearance between the piston at the end of the stroke and the valve-face and thus diminished losses to which the Lowell engine was subject. Moreover, the Lynn valves do not, like those at Lowell, leak with age.

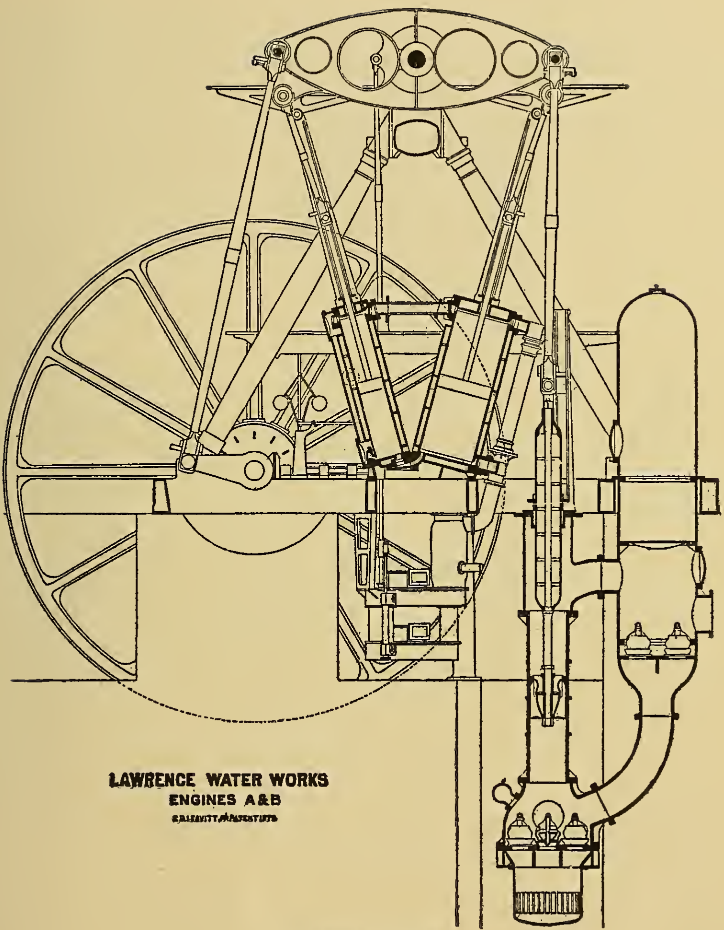
The whole effect of the Lynn design was to diminish condensation, loss of work between the cylinders and loss of steam in the clearances of the low-pressure cylinder by discharging it to the condenser. This engine was tested by Messrs. Worthen, Hoadley, Kirkwood, Hermany and Davis, and gave a duty of 103,923,215 ft. lbs. per 100 lbs. of coal, being the highest duty ever recorded in the United States up to that time. With it began an era of high duties in this country, which have ever been increasing, until it seems that there is but little more to be accomplished.

I shall dwell a little upon the Leavitt engines because in them now are to be found all those features that promote economy in steam-engines, and their development is interesting.

The Lynn engine was followed by those at Lawrence, which are of the same type, but larger. They were carried out better in detail at the steam end, but chiefly on account of great pump-friction the duty was lower, being only 96,186,979 ft. lbs. per 100 lbs. of coal. The official test was made by Messrs. Worthen, Hoadley and Davis, on May 2–6, 1876.

Mr. R. H. Buel tested these engines in July, 1879, after some changes had been made in the pumps and obtained a duty of 111,548,925 ft. lbs. per 100 lbs. of coal. A portion of the improvement was caused by better boiler performance.

Mr. Leavitt did not repeat this design, having seen the advantages of in-



LAWRENCE ENGINE.

verting the engine. He then placed the cylinders upon the tops of columns, the beam in pedestals in the bed-plate beneath and the main shaft in pedestals at one end of the bed-plate.

Two pumps instead of one, and a great many small pump-valves instead of a few large ones were used. The cylinders were placed as near together as possible, but for simplicity only the high-pressure cylinder was inclined.

By this design the economy of steam obtained at Lynn and Lawrence was realized, greater stability was obtained, shorter steam and pump connections were practicable, and two pumps could be used with great convenience. Moreover, most of the parts were more accessible than in the Lynn type.

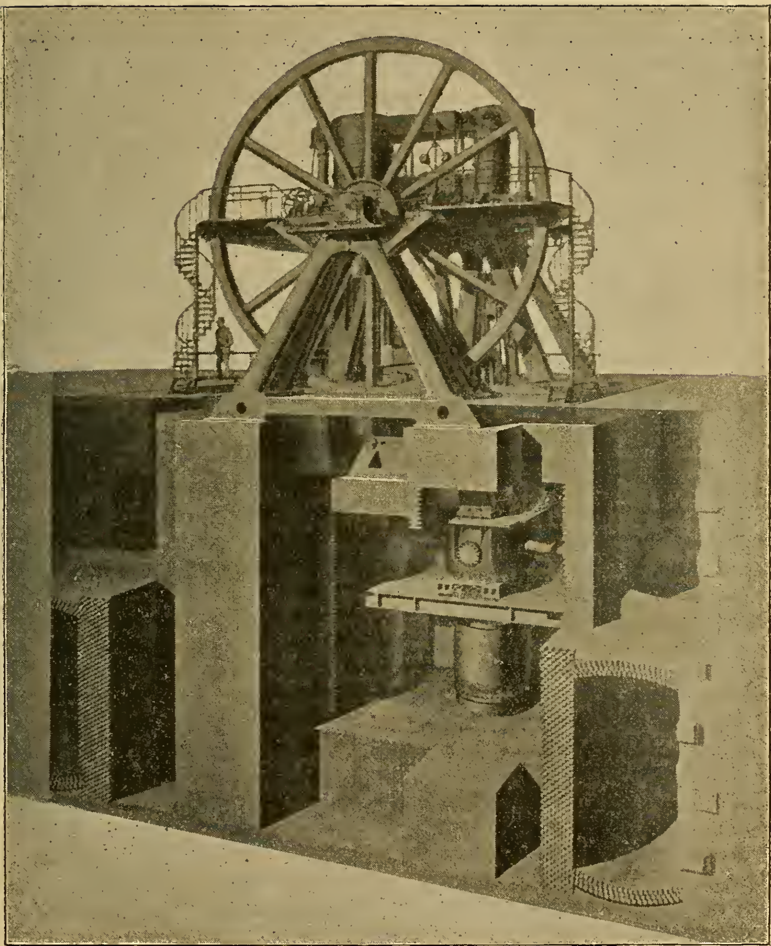
The inverted type just described is best illustrated by the pumping-engine "Ontario" at the Calumet & Hecla Mine. It has a vertical low-pressure cylinder 36 inches in diameter, and an inclined high-pressure cylinder $17\frac{1}{2}$ inches in diameter, the stroke of both being 5 ft., the maximum revolutions per minute giving a plunger speed of 330 feet per minute. This engine runs 24 hours a day 6 days in the week and is one of the the smoothest and best working pumping-engines in the country. It has been speeded up several times in order to keep up with the demand for water and thus far runs better with the higher speed. It has 72 suction and the same number of discharge-valves, both $5\frac{1}{4}$ inches in diameter and $\frac{3}{8}$ inches maximum lift. The pumps have differential plungers, each single acting on the suction, and double on the discharge.

The next Leavitt engines bearing new features are the Boston Sewerage Engines. While they resemble the Ontario, it will be noticed that both cylinders are vertical, Mr. Leavitt having by that time seen that by placing a cut-off-valve on the low-pressure cylinder there was no longer need of keeping the cylinders near together. By a proper determination of the point of cut-off in this cylinder most of the loss of work between the cylinders caused by unresisted expansion or drop is done away with.

Here again is seen for the first time a re-heating receiver between the cylinders for the purpose of drying the steam exhausted from the high-pressure cylinder. The re-heating is done by steam of boiler-pressure within many small brass tubes, around the outside of which the exhaust steam plays.

The cylinders of this engine are too large, the engine having been designed for a greater lift than that finally adopted, but notwithstanding the great expansion of the steam, and the slow speed, the engines use but 14 lbs. of steam per indicated horse-power per hour. The number of expansions with 96 lbs. of steam at the engine was 22, and the number of evolutions per minute about $13\frac{1}{3}$ corresponding to 240 feet of piston-speed per minute. Now this economy, notwithstanding unfavorable conditions, is without doubt due to steam-jackets and the re-heater.

The next Leavitt pumping-engine that deserves attention is the 16,000,000-gallon engine designed for the Louisville Water Co. of Louisville, Ky. This engine has steam-cylinders 27 in. and 54 in. by 10 feet stroke, and is to run 18 evolutions per minute giving a steam-piston speed of 360 ft. per minute. The engine, like the Ontario and Sewerage Engines, is inverted, with the beam under the cylinders, but unlike the Sewerage and like the Ontario has the fly-



Boston Sewage Engine.

wheel out at the end of the bed-plate. The plungers are two in number, are of the differential type and are connected to the beam at points between the ends and centre of the beam, so as to give a stroke of 7 ft. 6 in. to the plungers. This gives a plunger-speed of 270 ft. per minute. This engine is to work with 140 lbs. of steam by the gauge, and ought, if the jackets and re-heaters are as efficient as anticipated, to use somewhat less than 14 lbs. of steam per horse-power per hour.

This engine is remarkable in having very long pump-chambers on account of its location. The Ohio River water-level at Louisville varies some 50 ft., so that the engine proper is placed high and the pump reaches to the low water-level. Each pump is 61 feet long, 8 ft. inside diameter, and each plunger is 40 ft. long. There will be 143 suction-valves and 124 delivery-valves to each pump.

This engine is not only remarkable for the height of the pumps, but also for the weight of all the parts, it being the determination of the Water Co. to prevent breakage if possible. The total weight of the engine is 800 tons.

The Louisville engine is the last Leavitt compound pumping-engine built, and represents its highest development.

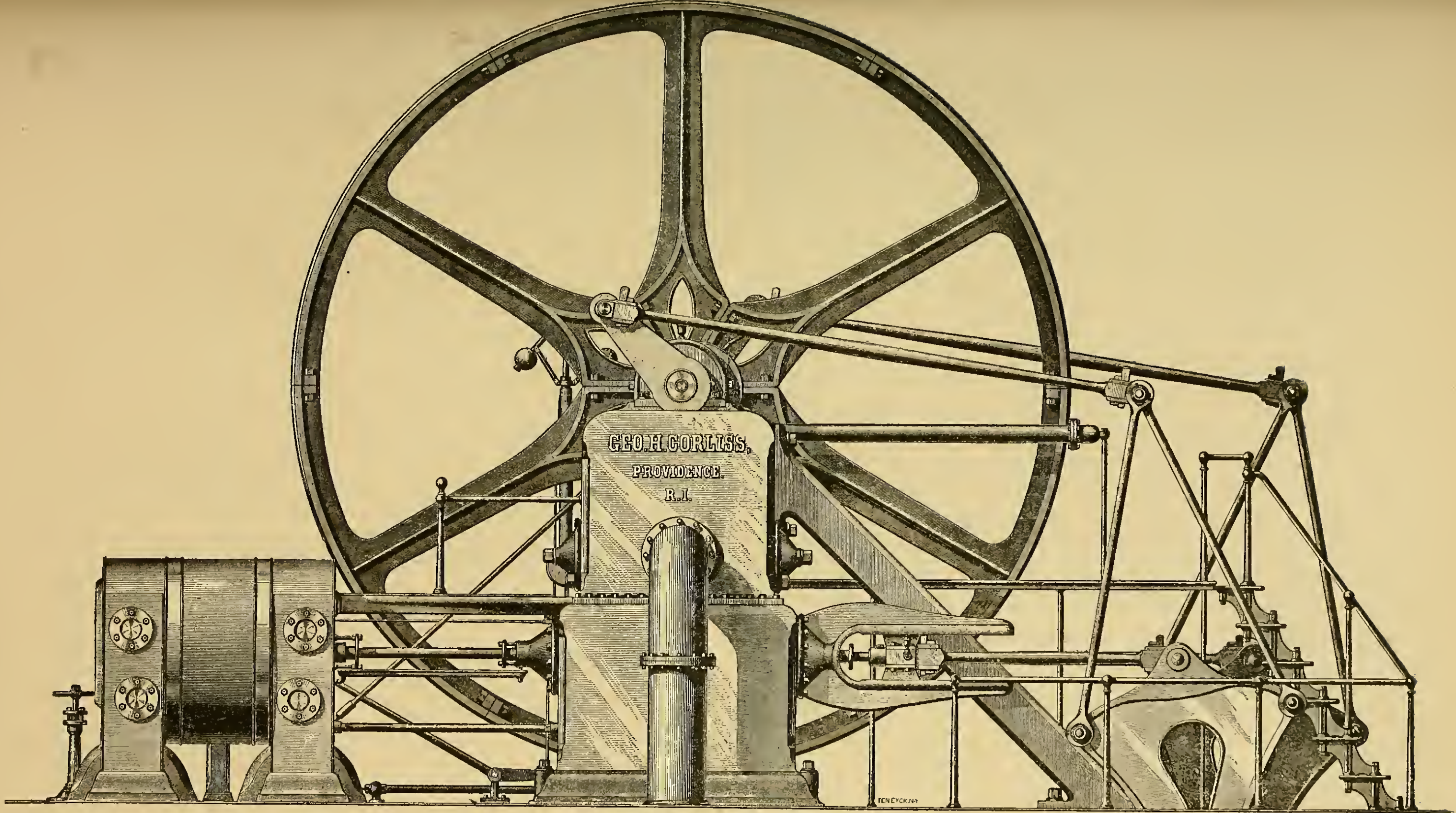
This was followed by a 60,000,000-gallons triple-expansion engine to carry 185 lbs. of steam, for the Calumet & Hecla Mines, but of this I am not at liberty to speak.

Following this came the new engine for the Chestnut Hill Pumping Station for the City of Boston, which is of 20,000,000 gallons capacity. This is a triple-expansion engine having cylinders 13.7 in. $24\frac{3}{8}$ in. and 39 in. $\times$ 6 ft. stroke, and has three plungers $17\frac{1}{2}$ in. diam. by 4 ft. stroke. The engine will make 50 revolutions per minute corresponding to a steam-piston speed of 600 ft. per minute and pump-plunger speed of 480 ft. per minute. The steam-pressure will be 185 lbs. by the gauge, giving about 30 expansions. The steam consumption ought to be below 12 lbs. per horse-power per hour.

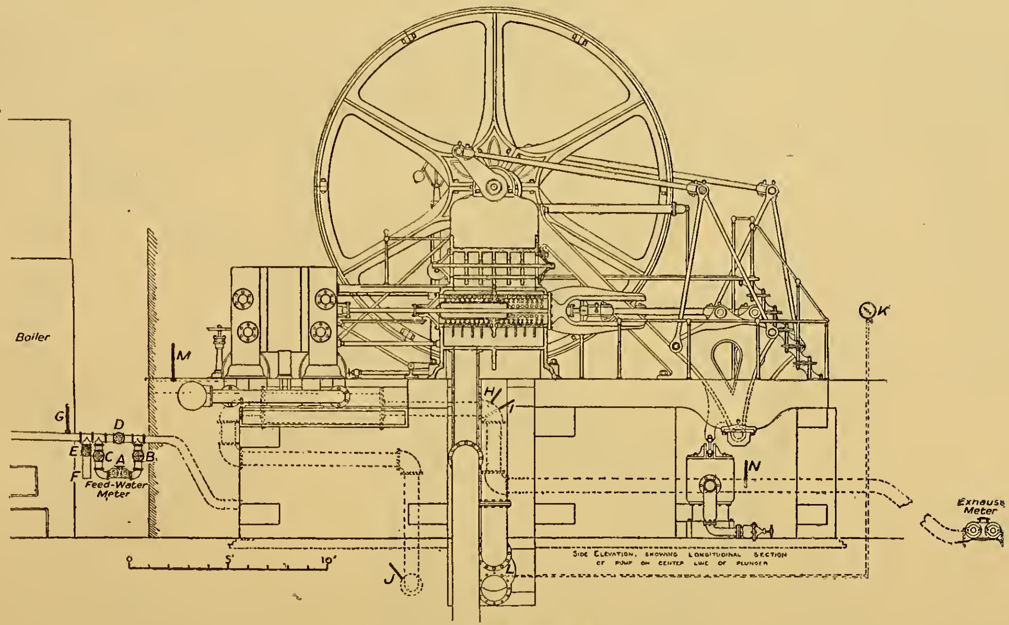
During the development of the Leavitt pumping-engine, Mr. George H. Corliss was giving much thought to the matter, and built two experimental engines, which he worked in his shops at Providence. His Pawtucket engine was started on Jan. 30, 1878, and tested in October, 1878, by Walter H. Sears and Isaac N. Scott. The duty per 100 lbs. of coal during a 24 hours' test was 133,522,060 ft. lbs., which is the highest duty ever recorded for a compound engine.

The Pawtucket is a cross-compound having cylinders 15 and 30 x 30, and runs 49 revolutions per minute. The pump-plungers, two in number, double-acting, at 10.52 in. diameter and 30 in. stroke. The steam-piston and pump-plunger speed is 245 ft. per minute.

This engine is remarkable in many particulars. It has beams that give a crank throw double that of the piston travel, the beams being built up partly of wrought-iron links of very light and lofty construction. It has not only surpassed all records of compound-engines in this country for economy, but is remarkable for having cost virtually nothing for repairs. This immunity from repairs is said to be due to the elasticity of its construction and the resulting diminution of shocks. It is also remarkable for having a great num-



Pawtucket Engine.



Pawtucket Engine.

ber of pump-valves, $2\frac{1}{4}$ in. in diameter with a lift of $\frac{1}{4}$ in. The aggregate area of these valves is equal to the area of the cross-section of the plunger. They are made of bronze annular discs $\frac{1}{32}$ in. thick, and while they slam on their seats they are so light and move so little that they neither injure themselves nor their seats.

This engine was tested by Prof. J. E. Denton and gave a duty of 127,350,000 ft. lbs. per 100 lbs. of bituminous coal and would have given 136,000,000 ft. lbs. if the boilers had evaporated 10 lbs. of water per pound of coal. The steam used per horse-power per hour was about $13\frac{3}{4}$ lbs. The cylinders are jacketed, but careful experiments show that the jackets have not in this case the usual value, saving only some 2 or 3 per cent. of steam. A source of economy of the engine is the location of a re-heater in the smoke-flue, through which the condensation from the receiver is passed and then returned to the low-pressure cylinder.

In 1881 Mr. Corliss erected a pair of compound vertical-beam pumping-engines at the Pettacouset pumping-station at Providence of 9,000,000 gallons capacity, guaranteed to give a continuous duty of 100,000,000 ft. lbs. per 100 lbs. of coal. The engines have one high-pressure cylinder under one beam 18 in. diam. and one low-pressure under the other beam 36 in. diameter, both strokes being 6 ft. Each engine works two 19 in. plungers with 36 in. stroke. The pumps have valves like those in the Pawtucket engine. This engine gave an average duty for one year of 106,048,000 ft. lbs., and on a test by Samuel M. Gray, during six days of about 12 hours each, including banking coal, a duty of 113,271,000 ft. lbs. per 100 lbs. of coal. The estimated duty of the engine, with banking coal deducted, was 138,035,000 ft. lbs.

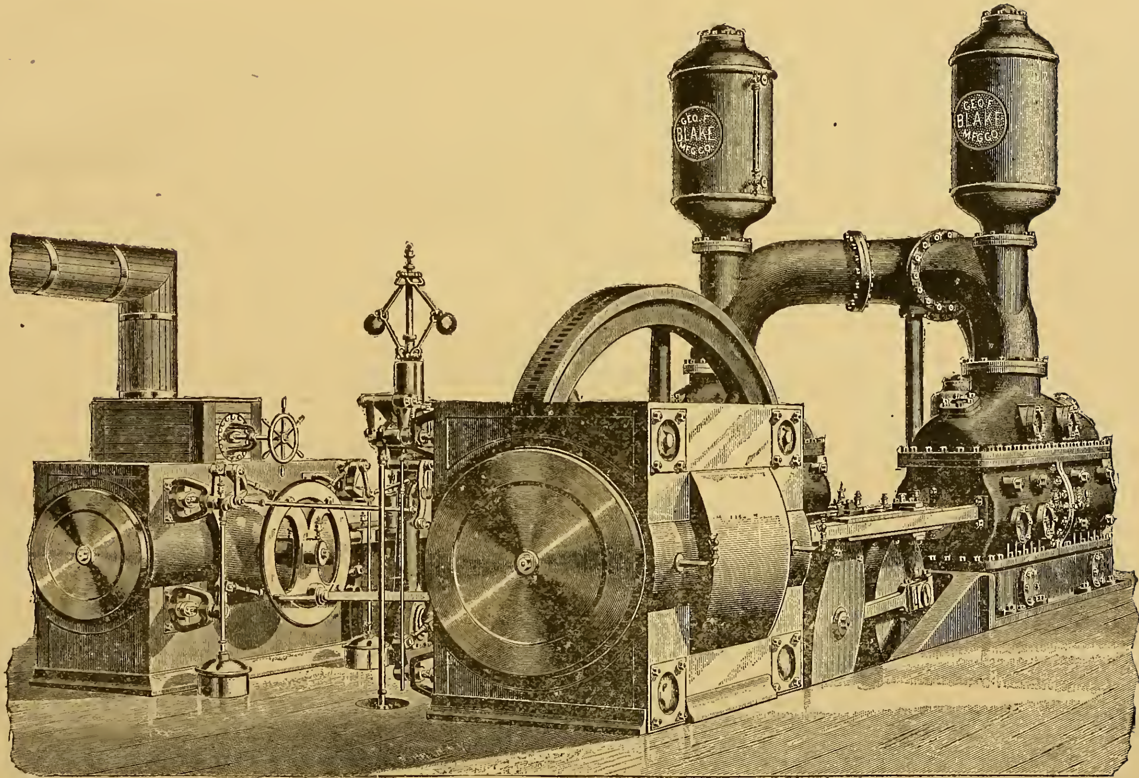
A second engine was put in at Pawtucket by Mr. Corliss, being in most respects like the first engine, and this ended Mr. Corliss' work in this kind of engineering.

Among the fly-wheel pumping-engines deserving great attention both on account of the merit of the arrangement of the cylinders and the great number in use, is the Gaskell engine. This accomplishes in a very perfect way what was sought by the first Leavitt design, viz.: opposite movements of high and low-pressure pistons and direct steam-passages from one cylinder to the other. This engine ought to be unsurpassed as an economical steam-user by any engine without a re-heater and a cut-off on the low-pressure cylinder. The usual amount of feed-water used by it per hour per horse-power is about 17 lbs., although occasionally it is less. At Philadelphia the amount reported is 14.94 lbs., or practically 15 lbs.

The pump-end of the Gaskell engine is distinguished by the use of numerous small rubber-faced valves, over openings $2\frac{1}{4}$ inches diameter, and lifting $\frac{5}{16}$ inch. The valves are exceedingly simple and are within cages screwed into the valve-plates of the pumps.

The engine is slow-running and has a small aggregate area of valve-opening, but there seems to be no reason why it should not run fast if ample valve and water-way area is given.

The usual duty of the Gaskell engine on trials appears to be 105,000,000 ft. lbs. per 100 lbs. of coal.



Blake Engine.

A newly-introduced compound fly-wheel pumping-engine is the Blake engine, of which six have been built. This engine has one high and one low-pressure cylinder and a Corliss valve-gear controlled by a governor. The gear is so made as to give a range of cut-off from 0 to $\frac{3}{4}$ stroke. It has two cranks at right angles to each other, a cut-off on the low-pressure cylinder and a re-heating receiver. It has all the usual means of economy and, as might have been expected, uses about 14 lbs. of feed-water per horse-power per hour.

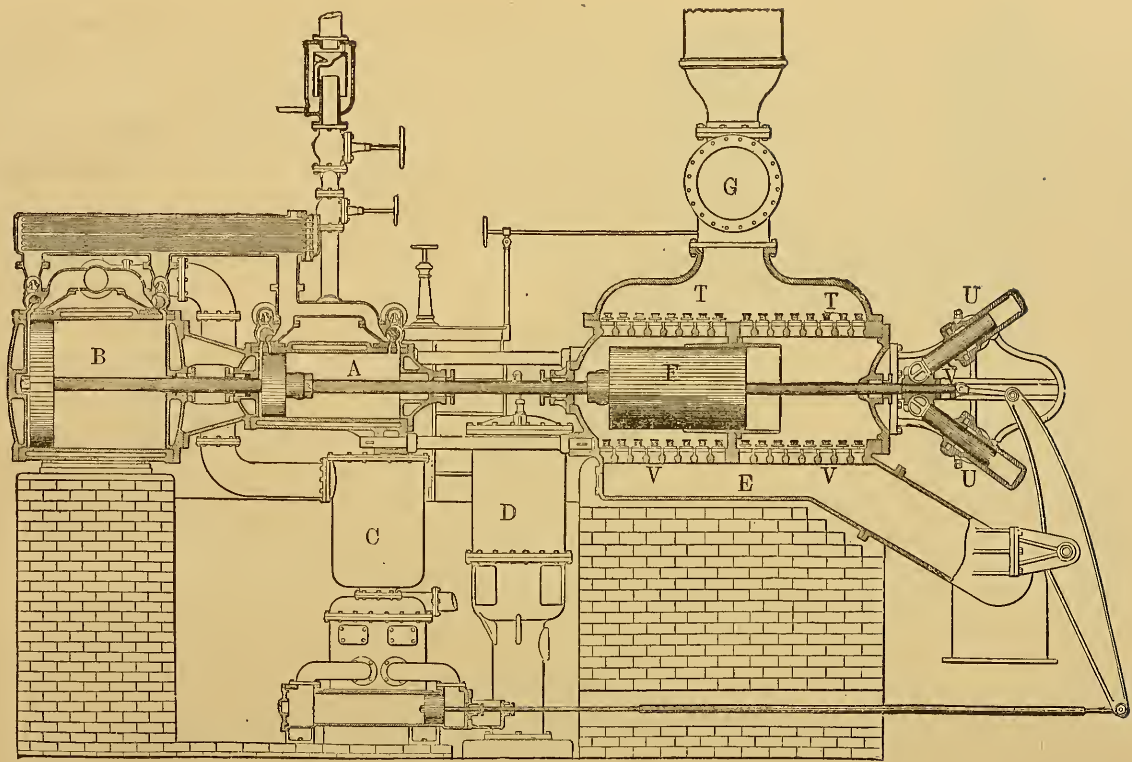
The pump-end has many small valves with a small lift, and aggregate opening of over $1\frac{1}{2}$ times the plunger-area. The usual duty to be expected is about 120,000,000.

One of the most interesting, important and scientific improvements in pumping-engines is that of elevating the direct-acting pumping-engine to the position of being a high-duty engine. The writer believes that there were several almost simultaneous inventions to accomplish this end, but that with which we are familiar is the high-duty pumping-engine manufactured by H. R. Worthington. The Worthington compound duplex pumping-engine, until this improvement was made, was a low-duty engine, because it could expand the steam only an amount due to the cylinder ratio, because it had large clearances, and could not compress steam in them up to the initial pressure. By means of the high-duty attachment and a change in the valve-gear most of these defects are eliminated, and the great advantage is gained that the steam can be cut off at any desirable point, and any degree of expansion obtained. There are two sets of valves to each cylinder, two for admission and exhaust and two for cut-off. The admission-valves of the cylinders on one side of the engine are operated by the machinery of the other side, while the cut-off valves are operated by the same side. This enables the peculiar relative motion of the two sides to be retained and still makes it easy to secure a cut-off at any point.

In any pumping-engine the resistance on the plungers is nearly constant, but if the steam is cut off the propelling effort so quickly diminishes that the plungers would stop unless a fly-wheel or some equivalent device should carry them on. The high-duty attachment accomplishes this in virtue of having plungers which have upon them pressure from the force-main augmented by a special accumulator. During the first half of the stroke of the engine these plungers are forced in by the surplus steam-pressure, and during the last half the accumulator pressure forces them out and completes the stroke, and thus fully compensates for the low steam-pressure due to the early cut-off, and resulting expansion.

The Worthington high-duty compound-engine appears to use about $16\frac{1}{4}$ lbs. of steam per horse-power per hour, and therefore uses $\frac{16.25}{14} = 1.16$ times as much steam as a good fly-wheel engine. It would, therefore, in general, give a duty of about 106,000,000 ft. lbs. per 100 lbs. of coal.

It would be interesting to inquire why this engine is not as economical as good fly-wheel engines. The writer has not had time to investigate this fully, but an inspection of the cards, and an examination of the engine shows that there is not, and cannot be a closure of the exhaust-valves early enough to



Worthington High Duty Engine.

compress the steam in the clearances, up to initial pressure, in either cylinder. If this were attempted the compensating cylinders would not have pressure enough to complete the stroke. If the stroke is not completed the clearance is increased with the attendant loss. The engine has the important features of a cut-off on the low-pressure cylinder and a re-heater.

The last engine that I shall consider is that of which a specialty is made by The Edward P. Allis Co. of Milwaukee, Wis. It is a vertical three-crank and three-pump triple-expansion engine with cranks 120° apart. The pumps are of the single-acting outside packed plunger-type making their strokes at equal intervals of the revolution and thus giving a steady flow of water. The steam-cylinders have the Corliss type of valve-gear, although I believe that in a few cases a single beat poppet-valve has been applied to the heads of the low-pressure cylinders for the purpose of reducing the clearance and thus diminishing the waste to the condenser. The engines are also provided with steam-jackets, and two re-heaters, one between each two cylinders. There is a variable cut-off on each cylinder, that on the high-pressure being under the control of a centrifugal governor. In a general way the engine is provided with all essential features for economy, and the performance must depend upon whether the designer has made the most of his opportunities.

Attention was called to this type and make of engine by the remarkable performance of the first one at Milwaukee, which was phenomenal in consequence of the low-pressure of steam used, viz.: 80 lbs. by gauge, and the ordinary rate of speed of $25\frac{1}{2}$ revolutions per minute. The amount of feed-water used per indicated horse-power per hour was 13.84 lbs., and the duty per 100 lbs. of coal was 129,403,204 ft. lbs.

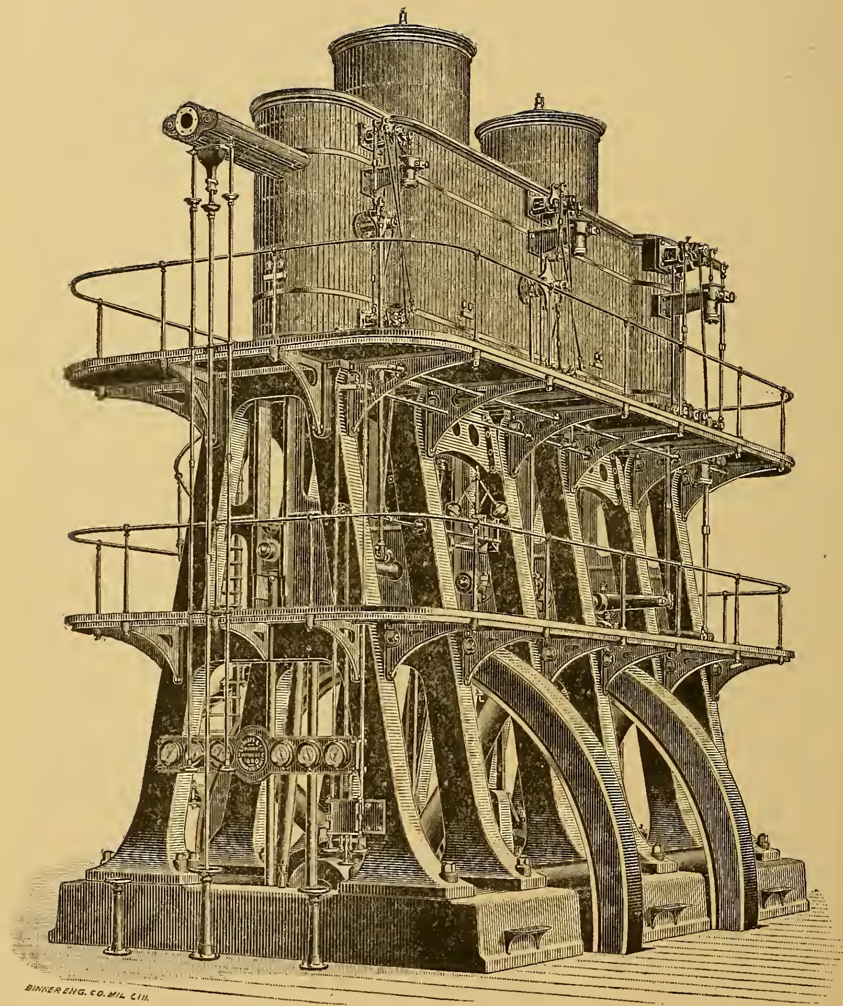
At St. Paul a similar engine gave a duty of 113,611,037 ft. lbs. with 90 lbs. of steam when running at 30.4 revolutions per minute.

At the Harrison Street Pumping Station, Chicago, this type of engine gave a duty on an eight hours' test of 140,416,679 ft. lbs. with 1,000 lbs. of steam, and used 12.675 lbs. of feed-water per indicated horse-power per hour. The steam-gauge pressure was 125 lbs. per sq. in., and the average speed $16\frac{2}{3}$ revolutions per minute.

The latest test of this type of engine was made by Prof. Carpenter of Cornell University at Milwaukee on March 25 and 26, 1893.

The engine has cylinders 28, 48 and 74×60, and three single-acting plungers 32 in. × 60 in. stroke, uses steam of 120 lbs. pressure by the gauge, and makes $20\frac{1}{3}$ revolutions per minute. The capacity is 18,000,000 gallons per day against a total head of 161.845 ft.

The duty per 100 lbs. of dry coal was	143,306,470	ft. lbs.
" " " 1,000 " " feed-water was	152,448,000	" "
" " " 1,000,000 " British heat units was	137,656,000	" "
" indicated horse-power was	573.87	
" friction " " "	52.91	
" " " " per cent	9.22	
" dry steam used per indicated horse-power per hour was	11.678	lbs.
British thermal units per indicated horse-power per hour	217.6	



Allis Triple Expansion Engine.

The amount of steam per hour per horse-power by this engine is nearly unequaled, if not quite, although it is said that Sulzer engines in Europe have used less steam, and that a Willans engine in London has used 11 lbs. of steam while being tested with every care to promote economy.

The clearances of the Allis engine last described are remarkably small, being as follows:

High-pressure cylinder	$1\frac{4}{10}$ per cent.
Intermediate	$1\frac{5}{10}$ " "
Low-pressure	$0\frac{777}{1000}$ " "

The piston and plunger speeds were $203\frac{1}{3}$ ft. per minute.

I have dwelt upon this type of engine because there are comparatively few of them in use and because they show what a triple-expansion engine can do. They are also interesting because they have used low steam-pressures. The triple-engine has the important advantage of more uniform pressures on bearings, and is therefore steady-running and less likely to heat its bearings than the double-expansion or simple engine.

Here I may properly refer to the importance of a governor to a pumping-engine, for with it the engine will come to a rest if a water-main bursts. In the case of the Worthington high-duty engine such a catastrophe will stop the engine by removing the pressure from the accumulator, and compensating cylinders, and thus deprive them of power to complete the stroke. The engine consequently stops.

Having now considered the prominent types of pumping-engines it is important to discuss the essentials to economy, and what we have to hope for in future. To assist in this I here tabulate the usual amounts of steam used per hour per horse-power by the various types, all having cut-off-valves on the high-cylinder and all steam-jacketed.

		Relative Value.
1. Compound fly-wheel without cut-off on low-pressure cylinder, and short steam-passages, lbs. per I. H. P. per hour	17 lbs.	0.735
2. Compound-duplex direct-acting with cut-off on low-pressure cylinder, and re-heater	$16\frac{1}{4}$ lbs.	0.769
3. Compound fly-wheel with cut-off on low-pressure cylinder, and re-heater	14 lbs.	0.893
4. Triple-expansion fly-wheel with cut-offs on intermediate and low-pressure cylinders and two re-heaters	$12\frac{1}{2}$ lbs.	1.

It is well-known that the greatest obstacle in the way of economizing steam is the prevention of condensation in the cylinders, and it is now well understood that this is chiefly dependent upon the range of temperature in the cylinders. While there is economy in the increased expansion that can be obtained from the higher pressures, there is a loss from condensation from the enlarged range of temperatures. If a lower pressure is used with the same number of expansions the range of temperature is reduced, for ex-

ample, in a triple-expansion engine carrying 185 lbs. of steam by gauge, and another carrying 125 lbs., the temperatures and ranges are as follows:

TRIPLE-EXPANSION ENGINE.

Gauge Pressure.	Temp. of high-pres. inlet steam.	Temp. of low-pres. exhaust steam.	Total Range.	Range in each cylinder.
185 lbs.	382°	142°	240°	80°
125 lbs.	353°	142°	211°	70°

While there is great economy to be realized from the earlier stages of expansion there is much less from the later stages; for example, the value of a pound of steam when following a piston full-stroke being: 1, that for four expansions or a quarter cut-off is 2.386 and that for one-tenth cut-off is 3.303. Diffs. 2.386 and .917. By the use of 125 lbs. gauge-pressure there are in general 20 expansions, and by the use of 185 lbs. gauge-pressure 28 expansions are available, and the relative values of a pound of steam in the two cases are 2.99 and 4.33 an important gain of $8\frac{1}{2}$ per cent. in economy. How much the condensation would be increased by the greater range of temperature, I am unable to state, as it follows no established law. In the case of the higher pressure the re-heating receiver becomes more efficient. In general, in seeking to economize, there is more to work upon in diminishing condensation because condensation in cylinders is so large, amounting to as much as 50 per cent. of the steam entering the engine in cases. In the Leavitt engine at Lawrence, economical as it was. the condensation amounted to 40 per cent. of the steam entering the cylinders. The use of the jacket in preventing condensation is well established. In many cases the saving from its use has been considerably over 10 per cent., but in some other cases it is much less, as, for instance, in the Pawtucket engine, it was 2 to 3 per cent. Its action is somewhat mysterious, and it cannot be predicted in any case what the saving will be. It is undoubtedly quite essential in the use of the higher pressures.

We have so far confined our attention to the steam-end of the engine, but there is some opportunity to economize at the pump-end. The amount of power in pumping-engines absorbed by friction of machinery and water is in general 8 or 9 per cent., but it has occasionally been as little as 5 per cent., and in the case of the Worthington high-duty engine at Lowell, was found to be only 2.8 per cent. All that can be done to minimize this friction is to send as little work from the steam-end to the pump-end through intermediate machinery as possible, and in this respect a direct-acting pump will probably always lead, although it may be questionable whether the compensating apparatus in the high-duty direct-acting engine may not absorb as much power as the connections and shaft in the fly-wheel engine. Considering the small total friction of the Pawtucket engine, and of the Newton engine in the first test, and of several direct-acting engines, this point may well be raised. Other points to be attended to are a reduction of the suction-lift so that the

pump will promptly and w ll fill, ample suction and discharge-valve areas, ample passages, and easy turns to assist in diminishing friction. Reduction of suction-lift is best effected by vertical pumping-engines. Experience indicates that if the areas through valves and water-passages are sufficient to give a water velocity of 250 ft. per minute or less they are ample. The water through the valves should be carefully guided and not too abruptly deflected. Efforts should be made to reduce shocks in pumps, for when they exist, more or less energy is wasted. This can be accomplished by small lift, and quick-seating valves, but the most perfect means of accomplishing this is by the mechanically-closed valves devised by Prof. Riedler of Berlin. This consists of an apparatus which allows the valves to lift by the water-pressure, but closes them by mechanical means before a return-current has time to form. It is said that by this means pumps can be run at almost any speed without shock. It is hoped that within a year the new Leavitt engine at the Boston Water Works will furnish us with an object lesson in this respect.

I do not wish to imply that the ordinary multiple automatic valve-pump cannot be run fast. The Pawtucket pumping-engine shows that it can with success for years, and there is a fly-wheel pumping-engine at Toronto designed by the George F. Blake Mfg. Co. that has for several years been running from 60 to 80 revolutions per minute. It consists of a Brown cross-compound engine with the piston-rods passing through the back cylinder-heads into Blake pumps with large valve-area. The pumps receive water under pressure, and they work with perfect quiet. It is a significant fact in this connection that many pumping-engines which have been speeded up have run best at the highest speeds, especially if they have low-suction lift and a large valve-area. This is undoubtedly due to the high velocity of the water and the proportionate inability to form a return-current by a reversal of the plunger-movement, and thus a slower seating of the suction-valves and resultant reduction of shock. It is conceivable that a pump might run so fast that the current of the water would move forward so rapidly that reversal would not occur, and that there could not be a shock. In that case the suction-valves would be slow in seating and seat by the pressure of the springs upon them.

The plunger-speed of pumping-engines is often, and in fact generally, limited to a certain number of feet per minute, without regard to the number of strokes made by the engine. There is wide-spread misapprehension on this point. The requirement mentioned is imposed in order to diminish shocks, but as the shock occurs at the instant of the reversal of the plunger it is evident that a limitation of reversals should be made. If the reversal has been made, and the shock has occurred, it is evident that the water can be moved with unlimited speed and safety. Engines are often built to make a certain number of revolutions per minute, and are so designed that the plungers have a shorter stroke than the steam-pistons in order to diminish the plunger speed. Such an arrangement can accomplish nothing, for the same amount of water must be displaced at each stroke whether the pump-stroke is long or short, necessitating the same amount of valve-area, the same acceleration and retardation of water, and often inconvenience in construc-

tion. With the shorter stroke the plunger diameter must be increased and in many designs this requires an undesirable diameter of pump in order to secure sufficient valve-area.

The superintendent of water works is often required to select between vertical and horizontal pumping engines. I trust that the time will come when no horizontal pumping engines will be made for they are likely to be a source of great expense in repairs in consequence of wearing cylinders and pumps from the friction caused by the weight of the moving parts. In some cases pistons act like planing machines on the cylinders, and leakage of steam and reduction of duty may result. The horizontal engine also requires more cylinder oil than the vertical, and the friction of the machine is greater in the former. It is notorious that the vertical engine for any service is more durable, reliable and economical than the horizontal.

Having considered pumping engines from various points of view, I wish to consider methods of testing. Within a few years a movement toward a rational system of testing pumping engines has occurred, which culminated in the appointment of a committee by the American Society of Mechanical Engineers to devise and report upon a standard method of conducting and reporting such tests. For a number of years it has been common to separate the engine from the boiler by specifying duty per a certain number of pounds of steam used by the engine, as 1000 lbs. As the engine does its work in virtue of heat carried to it, it is obviously better to specify duty in terms of a certain number of units of heats used by it and its necessary auxiliaries, such as re-heaters, jackets and feed pumps. The committee referred to reported in favor of this plan and recommended the use of 1,000,000 British Heat units, or in other words that the duty shall be the number of foot pounds of work done by the pump per 1,000,000 heat units absorbed by the engine. I propose to explain this in detail. When steam of a certain pressure, and therefore temperature, passes the throttle valve into the engine, each pound possesses a certain number of heat units, and knowing the number of pounds entering the engine by weighing the feed water it is an easy matter to compute the total amount of heat units that enter the engine in a given time. This steam passes out of the engine partly as steam and partly as water, at a temperature lower than that at which it entered. The engine has therefore used a certain number of heat units in doing its work. The temperature at the end of the process is called the temperature of rejection, and is practically the temperature of the feed water as it leaves the engine or any feed water heater with which the engine is provided, for the cycle takes place between the engine and boiler. If there are jacket and re-heater drains, their amounts and temperatures must be considered if it be practicable to return them to the boiler. It is obvious from this, that the hotter the feed water the less heat the engine uses, and the higher the duty will be. If independent feed pumps are used they must be considered a part of the engine, the steam used by them counted, and the temperature of the boiler feed if raised by these pumps must be taken for the temperature of rejection. If cold water is used for feed its temperature is the temperature of rejection. In such a test the initial pressure should be taken close to the engine so that the engine shall

not suffer from the condensation and wire drawing which may come from a long pipe, for which it is in no way responsible, and the temperature of rejection shall be taken as near the engine as possible so that it shall not suffer from a fall on account of a long feed pipe for which it is in no way responsible.

Now in regard to the foot pounds of work done by the pump end, this should be determined by multiplying the pressure against which the plunger acts including suction lift by its area of cross section and by the distance through which it moves. It will be observed that this method takes no account of the water pumped, for this can be determined by weir measurement or otherwise, and the contractor should be held as responsible for the capacity of the pump as for the duty.

The quality of the steam near the engine should be determined in order to accurately compute the amount of heat passing into the engine.

The propriety of leaving the boiler out is evident. It may be a poor evaporator, a bad primer, it may have good or bad coal, it may be fired well or badly, or it may be dirty, and for any of these the engine is not responsible. In order to protect the purchaser the boiler should be put in under a guarantee to evaporate so much water, when reduced to the equivalent of feed at 212 degrees and evaporation at that temperature, per pound of combustible consumed.

In this connection I wish to refer to the need of a standard coal for testing boilers, and I think it would be well for this Association to officially recommend the use of George's Creek Cumberland in lump form. This coal is recommended because it is easily procured, is good, and suffers less from exposure and transportation than some others. The lump form is recommended because it is nearer a standard state than fine coal, and is therefore a more definite thing. The boiler should not be held responsible for the incidents of transportation and exposure.

The duty of pumping engines is often greater on trials than in later service, but there are some exceptions, the Lynn and Lawrence engines being examples. If the coal used for heating and other services is deducted I should generally expect an increase of duty, for if the engine and boilers are not neglected all parts must work better and they are likely to be treated by more intelligence with increase of experience.

Finally I wish to draw your attention to the means of producing economy that are left to us. We must look to the steam end of our pumping engine for further improvement, as pump resistances are near a minimum at present. As before hinted the greates field is in preventing cylinder condensation, and while the triple expansion engine has done much when intelligently designed, it would seem that the quadruple engine is justifiable where coal is not cheap, and this with pressures easily and safely carried.

It would seem that the use of super heated steam offers the most promising field for the future in the prevention of condensation. In the past a durable super-heater has not been produced, but at present I am of the opinion that it can be. The next difficulty is to furnish sufficiently high temperature waste gases for super heating from the boiler without injuring the boiler per-

formance so as to counterbalance the gain from super heating. Recent experiments that I have made with boilers of the locomotive type burning from 16 lbs. to 70 lbs. of coal per square foot of grate per hour show plainly that evaporations of over 13 lbs. of water from and at 212 degrees per pound of combustible can be obtained when gases are escaping at 600° F. This is sufficient for considerable super heating, and such a boiler performance can be obtained with induced artificial draft.

The remainder of the field for economy is chiefly to utilize all waste heat from engine and boiler for heating feed water.

In conclusion I predict that the most economical steam plant of the future will be designed as follows :

The boiler will be of the locomotive type having a ratio of heating to grate surface of 75 or 80 to 1, working with over 200 lbs. of steam, having artificial draft and burning 30 or 40 pounds of coal per square foot of grate per hour. This type of boiler is selected because it is the most economical of all boilers, either when forced or not, will stand the highest pressures, extreme forcing, and general abuse without harm for many years. It is the pioneer of high pressures throughout the world, and its success under the most trying conditions, shows it to be perfectly safe.

The engine used will be a moderately fast running vertical quadruple expansion, furnished with steam, super-heated by the waste gases of the boiler. The cylinders will be steam jacketed, and the initial steam in the high pressure cylinder may be wire drawn considerably below the boiler pressure. There will be re-heaters between the cylinders, the condensation from the working steam side of which will be passed through evaporators in the smoke flue of the boiler and returned to the most advantageous point of the engine.

The live steam should not evaporate any of this condensation, on account of the great amount of heat required, but should merely prevent condensation. The condensation from the live steam side of the re-heater should be returned to the boiler. There will be a feed water heater in the low pressure exhaust pipe, and this water will have added to it the rejected heat of the auxiliary engines if there are any, and will then pass through an economizer in the flue beyond the super-heater and evaporator on its way to the boiler. The jacket condensation will pass to the boiler independently. The smoke box end of the boilers will be near the engine in order to diminish the dissipation of the super-heat of the steam which occurs very readily.

In the case of pumping engines the pumps will have a large valve area with many small automatic valves or with few large automatic lifting and mechanically closing valves.

TOPICAL DISCUSSION.

June 15, 1893.

THE FILLING OF SERVICE PIPES BY SEDIMENT OF TUBERCULATION.

THE PRESIDENT. I suppose it is well understood that the ideal service pipe has not yet been invented, whether you use lead or wrought-iron or cement-lined or enamelled pipe or any other kind. There is some objection to every one of them, through different waters have different effects on the pipe, and we have had different experiences, and it seems to me we might derive some benefit from an interchange of our experiences in this direction. I will call upon Mr. Noyes to tell us something about the service pipes in Newton.

MR. NOYES. Our works were constructed in 1876, and the engineer in charge made as careful investigation as he could within the limited time, as to how the different pipes would act in water which is supplied to the city. The tests showed that the tar-coated wrought iron pipe gave a good result, and it was almost universally used for the first two years ; but it was found in practice that it filled up very rapidly, and although there are some of the pipe that have been in service up to the present time, yet they are almost entirely filled up. They have used the various classes of enamelled wrought-iron pipe, but they gave unsatisfactory results. They are using now lead pipe altogether or the galvanized iron pipe. A limited amount of galvanized iron pipe has been in use since the work was constructed, and it shows little or no filling up. The superintendent who has charge of the maintenance and becomes conversant with any services which may be cut out, tells me that he has had no case of either rust or filling up with galvanized iron pipe ; so that all the services that are put in now are either lead or galvanized iron at the election of the consumer.

THE PRESIDENT. Does any one present know of any cases in which lead pipe has filled up.

MR. FULLER. I had some samples of pipe at one of the meetings last winter, taken from the Wellesley water works, and, as Mr. Noyes has said, the tar-coated wrought-iron pipe has given very poor results in six or seven years, it is practically good for nothing, and is almost entirely filled with rust or corrosion. We put in a few galvanized services, and one of those was cut out a while ago to insert a meter, and that also showed signs of rust and corrosion. For the last four or five years we have used the cement-lined wrought-iron, and except for a little trouble occasionally from the cement coming off we have had no trouble with it whatever. It seems to me that either lead or the cement-lined wrought-iron is the best service pipe we have. I do not know how satisfactory the iron lead-lined pipe would be found, although it seems as though that might prove to be a good pipe, but the plain wrought-iron pipe is evidently not suited for service pipe work. I know the delivering capacity of a pipe in my own house, which was put in about 1886, is not more than about a seventh now, of what it was when it was put in. That is tarred iron pipe.

THE PRESIDENT. We use in Taunton a cement-lined wrought iron pipe, and we have a good many complaints of poor service and frequently have to clean out the pipe, and sometimes put down new pipe. I find in looking over the records that as a rule those services have been in for ten or a dozen years, but sometimes we have had trouble with services that have not been in more than a year or two. In most cases the trouble has been either at the corporation cock, the service cock or at the couplings. The couplings were lined by a thimble of about three-quarters inch bore which was put in the centre of what had been an inch pipe, this thimble being made of composition, nickel plated, and then the space between that and the iron coupling packed in with solder; but even then the cement would get broken off the pipe a little, and there was some contact between the iron and the thimble, so that there was a galvanic action, and I have seen those couplings so obstructed that there wasn't a space as big as my little finger for the passage of the water.

And there is something else besides tuberculation and sedimentation that sometimes occurs. We had a complaint one day of a service being suddenly stopped. In most cases the stoppage is gradual, but in this case I have in mind it was sudden. When disconnection was made at the goose-neck, the 18 inches of lead, an eel was found to have stopped up the whole length of that lead, his head just pushing into the union, and at the time he was found he was alive. On another occasion there was a similar sudden stopping, and in that case the eel had his head just stuck at the corporation. The foreman was sent to look after it, and he said he couldn't get it out. Said I, "You must do it; it won't do to have him die there;" and finally he got him out. In both these cases the eel was a foot long and as big around as the base of my thumb. He could not have got in through the screens or gone through the valves of the pump unless he was very small and then grown. I suppose these eels are in the pipes travelling around and having a good time, and once in a while they get into a place where they give us this trouble.

The character of the water has something to do with the filling up of the pipe, as well as the character of the pipe. It is well understood that water that is imperfectly filtered, especially when the water contains iron, is susceptible to the growth of an organization called crenothrex, and that is bound to fill up the pipes. I have strong hopes that when we get through using Taunton river water, or use it with something else, we shall not have so much trouble from tuberculation and sedimentation in the service pipes.

MR. BROWN. I remember on one occasion the water stopped in a 2-inch pipe, and in the nipple from the tap in an 8-inch main we found an eel that completely filled it. He had got his head through and stuck there. He measured three feet six inches long by six inches in circumferance. As to how he got there I can't say, and it is the only instance of the kind I have known on the works. With regard to service pipe, I will say we use wrought-iron cement-lined. We have eight or nine hundred services which have been in twenty years, and perhaps a dozen a year bother us by filling up. The trouble is mostly with the Ts and elbows. We have very little trouble with the couplings, and they stand freezing better than anything else we have.

Out of perhaps three or four hundred services frozen last winter but twenty-five were cement-lined.

Mr. Beals. I recollect one inch and a half pipe we found entirely filled. It was an enamelled iron pipe, the only one of the kind we had in, and upon examination we found that the enamel had flaked from the pipe and gone forward under the pressure of the water and finally filled the pipe. It was a service which was using a great deal of water. Most of our services are cement lined pipe. At times, when the lining was not perfect, where the two joints are screwed together, and where the water reaches the iron, we find a little deposit of rust around the coupling. But during our eight years of experience we have never yet had to take out a service pipe because of a deposit or incrustation stopping the pipe. In the case of this enamel pipe spoken of, we we took it out, and as the customer was a large one we ran a special 4-inch main clear to the cellar of his place. He has a 2-inch meter, and is using some 50,000 gallons a day.

Mr. Chase. The liquid which we supply our consumers is a dark brown surface water, common to the coast of the Southern States and, coming from the cypress swamps, has quite a large amount of tanic acid in it, as I am informed, which has a very corrosive effect upon iron. The first pipe we used for services was the enamel pipe. After a year or two we found it was not giving satisfaction, showed very pronounced signs of filling up, and we changed to galvanized iron, and have used that for the last ten years with very gratifying success. The only vulnerable points are at the fresh cut ends. I have seen ordinary wrought iron pipe three-quarters of an inch in diameter, practically filled up in two or three years by tuberculation and sedimentation. We found in a short time that the corporation stops we used did not project far enough through the shell of the iron pipe, and that a sort of excrescence or tubercle was formed over that, entirely stopping up the tap. We now use a corporation which extends through the pipe at least a half an inch, and we have had no trouble. It has become necessary to provide means for reaming out the stops which fill up, and I suppose we have half a dozen every year, increasing in number; and for that we use a drill running through a stuffing box which is screwed on the corporation. Very much the same device as used for tapping the cement or "mud" pipes, as our friend Walker calls them. We occasionally have a stoppage by a fish getting his head in, but all we do then is to punch him through and let him go on and say nothing about it.

OBITUARY.

CHARLES W. S. SEYMOUR—Superintendent Water Works, Hingham, Mass. Died October 16th, 1893. Aged 54 years, 1 month. Joined this Association April 21st, 1885.

WILLIAM DIXON—Formerly Superintendent Mt. Pleasant, Mich. Born at Manchester, England. Died September 12th, 1893. Aged 44 years, 7 months. Joined this Association June 16th, 1886.

DR. CHARLES F. CREHORE—Member of the Newton Water Board from 1880 to 1888 and was largely instrumental in procuring the improved system of water-works for the City of Newton. Born at Newton Lower Falls. Died November 7th, 1893. Aged 65 years, 3 months Joined this Association April 21st, 1885.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VIII. March, 1894. No. 3.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

QUARTERLY MEETING.

Parker House, Boston, Mass., December 13, 1893.

The following members and guests were present:

MEMBERS.

Everett L. Abbott, New York City; Charles H. Baldwin, Boston, Mass.; Lewis M. Bancroft, Reading, Mass.; George E. Batchelder, Worcester, Mass.; Joseph E. Beals, Middleboro, Mass.; Nathan B. Bickford, Boston, Mass.; William R. Billings, Taunton, Mass.; Dexter Brackett, Boston, Mass.; Arthur W. F. Brown, Fitchburg, Mass.; George F. Chace, Taunton, Mass.; E. J. Chadbourne, Boston, Mass.; Charles E. Chandler, Norwich, Conn.; John C. Chase, Wilmington, N. C.; William F. Codd, Nantucket, Mass.; Freeman C. Coffin, Boston, Mass.; R. C. P. Coggeshall, New Bedford, Mass.; H. W. Conant, Gardner, Mass.; Byron I. Cook, Woonsocket, R. I.; George E. Evans, Boston, Mass.; B. R. Felton, Marlboro, Mass.; Desmond FitzGerald, Boston, Mass.; F. F. Forbes, Brookline, Mass.; Frank L. Fuller, Boston, Mass.; George W. Fuller, Lawrence, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; J. A. Gould, Jr., Boston, Mass.; E. H. Gowing, Boston, Mass.; Richard A. Hale, Lawrence, Mass.; John L. Harrington, Cambridge, Mass.; John Harris, Waltham, Mass.; John C. Haskell, Lynn, Mass.; V. C. Hastings, Concord, N. H.; Allen Hazen, Lawrence, Mass.; Horace G. Holden, Nashua, N. H.; Patrick Kieran, Fall River, Mass.; George A. Kimball, Boston, Mass.; Thomas C. Lovell, Fitchburg, Mass.; William J. Luther, Attleboro, Mass.; W. E. McClintock, Boston, Mass.; William McNally, Marlboro, Mass.; James W. Morse, Natick, Mass.; Hiram Nevons, Cambridge, Mass.; Albert F. Noyes, Boston, Mass.; Weaver Osborn, Fall River, Mass.; George S. Rice, Boston, Mass.; Walter

H. Richards, New London, Conn.; George J. Ries, Weymouth Centre, Mass.; J. W. Ringrose, New Britain, Conn.; Henry W. Rogers, Haverhill, Mass.; John D. Shippee, Holliston, Mass.; George A. Stacy, Marlboro, Mass.; William W. Starr, Jr., Bridgeport, Conn.; Edwin A. Taylor, Boston, Mass.; Lucian A. Taylor, Boston, Mass.; Robert J. Thomas, Lowell, Mass ; M. M. Tidd, Boston, Mass.; W. H Vaughn, Wellesley Hills, Mass.; Charles K. Walker, Manchester, N. H.; H. A. Warren, St. Albans, Vt.; John C Whitney, West Newton, Mass ; Horace B. Winship, Norwich, Conn ; George E. Winslow, Waltham, Mass., James M. Betton, Boston, Mass ; E. L. Ross, Chapman Valve Mfg. Co., Indian Orchard, Mass.; M. H. Crawford, Boston, Mass.; F. H. Hayes, Deane Steam Pump Co., Holyoke, Mass.; A. H. Davis, William H. Gallison, Boston, Mass.; J. A. Tilden, Hersey Mfg. Co., South Boston, Mass.; William d'H. Washington, The Hydraulic Construction Co., New York; Henry F. Jenks, Pawtucket, R. I.; S. V. Adams, Peet Valve Co., Boston, Mass.; William J. Ranton, Syracuse, N.Y.; H. H. Kinsey, Rensselaer Mfg. Co., Troy, N. Y.; Mr. Seamans, Perrin, Seamans & Co , Boston. Mass.; I. W. Dodge, Standard Thermometer Co., Boston, Mass ; H. C. Folger, secretary Thomson Meter Co.. Brooklyn. N. Y.; G. H. Carr, Union Water Meter Co., Worcester, Mass.: Jesse Garrett, R. D. Wood & Co., Philadelphia, Penn.

GUESTS

John M. Burleigh, South Berwick, Me.; D. W. Darling, Worcester, Mass.; Carlton Davis, Newton, Mass.; Loring H. Farnam, Boston, Mass.; Harry Gould, Boston, Mass.; F. B. Johnson, Waltham, Mass.; C. W. Mann, Methuen, Mass.; P. McCabe, New Britain, Conn.; J. J. Moore, Hingham, Mass.; S. H. Taylor, New Bedford, Mass.

The following new members were elected :

RESIDENT ACTIVE.

W. L. Blossom, Civil Engineer, Boston, Mass.; John M. Burleigh, Supt., South Berwick, Me.; Frank L. Fales, Civil Engineer, Lawrence, Mass.; Loring N. Farnham, Civil Engineer, Boston, Mass.; Henry B. Wood, Engineer Street Department, Boston, Mass.

NON-RESIDENT ACTIVE.

Michael A. Connell, Supt. St. Hyacinth, P. Q.; H. C. Landon, Civil Engineer, Little Falls, N. Y.; J. A. Marion, Civil Engineer, Montreal, Can.; D. S. Merritt, Supt., Tarrytown, N. Y.; Melnor P. Paret, Civil Engineer, Baltimore, Md.; Vaughan M. Roberts, Civil Engineer, Toronto, Can.; J. Waldo Smith, Civil Engineer, Montclair, N. J.; Jay M. Whitham, Hydraulic Engineer, Philadelphia, Pa.

ASSOCIATE.

The Edw. P. Allis Co., Pumping Engines, Milwaukee, Wis.
F. B. Hawkins, Cast Iron Pipe, New York City.
H. B. Ternby, Agent Repauno Chemical Co., Boston, Mass.

Mr. F. F. Forbes, Superintendent of the Brookline Water Works, gave a description of the covered reservoir at Brookline.

Mr. George E. Winslow, Superintendent, Waltham, read a paper giving a general description of the Waltham source of supply, and he was followed by Mr. F. P. Johnson, City Engineer of Waltham, who gave an account of the work of covering the basin and well. The papers were discussed by Mr. Fuller, Mr. Noyes, Mr. Johnson, Mr. Forbes, Mr. Walker, Mr. Tidd, Mr. Coffin and Mr. FitzGerald.

Adjourned.

ADJOURNED MEETING.

Young's Hotel, Boston, Mass., January 10, 1894.

The following members and guests were present :

MEMBERS.

Everett L. Abbott, New York City; Charles H. Baldwin, Boston, Mass.; George E. Bachelder, Worcester, Mass.; James E. Beals, Middleboro, Mass.; William R. Billings, Taunton, Mass.; George Bowers, Lowell, Mass.; Dexter Brackett, Boston, Mass.; Arthur W. F. Brown, Fitchburg, Mass.; John M. Burleigh, South Berwick, Me.; John T. Cavanagh, Quincy, Mass.; George F. Chace, Taunton, Mass.; John C. Chase, Derry, N. H.; R. C. P. Coggeshall, New Bedford, Mass.; Byron I. Cook, Woonsocket, R. I.; George K. Crandall, New London, Conn.; Edwin Darling, Pawtucket, R. I.; Horace L. Eaton, Somerville, Mass.; John W. Ellis, Woonsocket, R. I.; Loring N. Farnham, Boston, Mass.; B. R. Felton, Marlboro, Mass.; F. F. Forbes, Brookline, Mass.; Z. R. Forbes, Brookline, Mass.; Frank L. Fuller, Boston, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; E. H. Gowing, Boston, Mass.; John C. Haskell, Lynn, Mass.; Louis Hawes, Boston, Mass.; Clemens Herschel, New York City; Horace G. Holden, Nashua, N. H.; Joseph L. Kenney, Lewiston, Me.; E. W. Kent, Woonsocket, R. I.; Willard Kent, Woonsocket, R. I.; Patrick Kieran, Fall River, Mass.; George A. Kimball, Boston, Mass.; Thomas C. Lovell, Fitchburg, Mass.; W. E. McClintock, Boston, Mass.; D. S. Merritt, Tarrytown, N.Y.; Frank L. Northrop, Milford, Mass.; Albert F. Noyes, Boston, Mass.; Edward H. Phipps, New Haven, Conn.; Dwight Porter, Boston, Mass.; Waldo E. Ramson, Uxbridge, Mass.; Walter H. Richards, New London, Conn.; George J. Ries, Weymouth Centre, Mass.; George O. Saunders, Hudson, N. H.; F. J. Shepard, Derry, N. H.; George A Stacy, Marlborough, Mass.; Frederick P. Stearns, Boston, Mass.; Lucian A. Taylor, Boston, Mass.; Robert J. Thomas, Lowell, Mass.; M. M. Tidd, Boston, Mass.; W. H. Vaughn, Wellesley Hills, Mass.; Charles K. Walker, Manchester, N. H.; Joseph Wallers, Fall River, Mass.; Horace B. Winship, Norwich, Conn.; George E. Winslow, Waltham, Mass.; E.

Worthington, Jr., Boston, Mass.; A. H. Broderick, Chadwick Lead Works, Boston, Mass.; E. L. Ross, Chapman Valve Mfg. Co., Indian Orchard, Mass.; M. H. Crawford, Boston, Mass.; Charles H. Eglee, Flushing, N. Y.; A. H. Davis, William H. Gallison, Boston, Mass.; J. E. Spofford, Hersey Mfg. Co., South Boston, Mass.; Henry F. Jenks, Pawtucket, R. I.; S. V. Adams, Peet Valve Co., Boston, Mass.; H. L. Bond, Perrin, Seamans & Co.; Boston, Mass.; Wilmer Reed, Burlington, N. J.; I. W. Dodge, Standard Thermometer Co., Boston, Mass.; E. J. Snow, Thomson Meter Co., Brooklyn, N. Y.; J. P. K. Otis and G. H. Carr, Union Water Meter Co., Worcester, Mass.; E. H. Rice, Walworth Mfg. Co., Boston, Mass.; Jesse Garrett, R. D. Wood & Co., Philadelphia, Pa.; H. A. Gorham, secretary The George Woodman Co., Boston, Mass.; H. B. Ternby, Boston, Mass.

GUESTS.

A. A. Blossom, Salem, Mass.; B. Bourne, Boston, Mass.; E. W. Bush, New London, Conn.; L. E. Daboll, New London, Conn.; D. W. Darling, Worcester, Mass.; H. P. Gallup, Ashmont, Mass.; J. M. Hetherton, Jr., New York City; Mr. Moore, Boston, Mass.; F. S. Newcomb, New London, Conn.; T. P. Nichols, Lynn, Mass.; Thomas H. Rogers, Nashua, N. H.; J. V. Reht, Peabody, Mass.; F. A. Snow, Providence, R. I.; S. H. Taylor, New Bedford, Mass.; A. B. Tower, Holyoke. Mass.; William F. Williams, New Bedford, Mass.

The Secretary presented applications for membership from the following named gentlemen, who were elected:

RESIDENT ACTIVE MEMBERS.

Theodore C. Bates, Water Commissioner, North Brookfield, Mass.; Francis Batcheller, Water Commissioner, North Brookfield, Mass.; Frank A. Barber, Civil Engineer, Brockton, Mass.; L. E. Daboll, Superintendent, New London, Conn.; Sidney G. Walker, Boston, Mass.; William S. Johnson, Civil Engineer, Brockton, Mass.; E. W. Clark, Civil Engineer, Jamaica Plain, Mass.; T. P. Nichols, Member Water Board, Lynn, Mass.

ASSOCIATE MEMBERSHIP.

Franklin A. Snow, Civil Engineer and Contractor, Providence, R. I.; William A. Harris, Selling Agent, Pratt & Cady Co., Hartford, Conn.

The President announced that the Executive Committee had voted to hold the next annual convention at Boston in June.

Mr. L. A. Taylor opened the discussion upon the subject, "The Construction of Reservoir Embankments," describing the reconstruction of a dam for the Worcester Water Works, on Lynde Brook. The subject was further discussed by Messrs. Darling, Freeman, Brackett, Tidd and Fuller. Mr. Freeman gave an account of the circumstances and the causes of the break in the Portland, Me., Reservoir, and Mr. Brackett explained how the repairs were made.

Experience papers were presented by Mr. John C. Chase on "A Cheaply Constructed Covered Reservoir;" and by Mr. George A. Kimball on "A Method of Recording the Location of Water Mains and Services."

Adjourned.

"COVERED RESERVOIR AT BROOKLINE, MASS."

BY

F. F. FORBES, SUPERINTENDENT.

(Read December 13, 1893.)

It is not my purpose in this short paper to touch on the history of covered reservoirs now in use in various parts of the world, or those which existed in old Roman times, for we all are more or less familiar with their construction; but rather to confine myself to a description of the covered reservoir in Brookline, and to a recital of some ideas which came to my mind whilst engaged in its construction, and also from studies of the subject in a general way.

It will not take one long to discover that a covered reservoir differs widely in most of its details from an open one. Also that certain problems connected with all hydraulic work will demand here much more care and attention.

Again, the cost of the class of reservoirs now under consideration must be large, consequently their size will be reduced to the minimum. And it follows that the smaller the capacity the greater and more sudden must be the fluctuation of the water in it. A fluctuation so great that most of the open reservoirs as now constructed would be ruined by it in a short time. This item forms one of the problems just alluded to.

It is therefore plain that a covered reservoir must be built so thoroughly and well that it can be filled today and emptied tomorrow without injury to itself, and so on indefinitely. When we bear these facts in mind, the subject becomes a difficult one, and we see that not only should the design be carefully studied, but that it is equally important that the work should be done in the most faithful manner.

The description of the reservoir in Brookline and the way in which we attempted to build a lasting structure, is as follows:

The reservoir is simply a masonry chamber 91.33 feet square at the bottom, and 94.00 feet square at the springing line of the covering arches ; with a depth of 19.2 feet from the overflow, giving a capacity of 1,200,000 gallons.

The batter of the walls is 1.34 feet. The roof is formed of a series of brick arches, and the bottom is covered with cement concrete. The inside of the walls are plastered with Portland cement. It will thus be seen that the whole inside of the reservoir can be cleaned as completely as an earthen dish.

No gate chamber is connected with the reservoir ; the inlet pipe, which also serves as an outlet, and the drain pipe enter the reservoir directly through the walls. The gates controlling these pipes are 500 feet distant at a point where the pipes come to the usual grade for street mains.

The overflow discharges into the open reservoir immediately adjoining. The side walls are $9\frac{1}{2}$ feet and $8\frac{1}{2}$ feet thick at bottom, and are built of

Roxbury pudding stone, laid in American cement mortar. They extend $3\frac{1}{2}$ feet below the bottom of the reservoir, and are started on 4 inches of American cement concrete. Great care was used to make certain that no spaces should be left in the wall, and to insure this, many barrels of cement in the form of thin gruel were poured down around the larger stone, and in fact it was the usual custom to grout thoroughly each course of stone.

Of course the contractor rather objected to such a lavish use of cement, but as the specifications required absolutely no voids in the stone work, there was little room for complaint.

The pier foundations, $3\frac{1}{2}$ feet square, built also of Roxbury pudding stone, were started on a Porland cement concrete base 5 feet square and 4 inches thick.

The piers, 2 feet square, were built of hard burnt brick laid in American cement mortar to a point below the skew-back for the lintels, and above this in Portland cement mortar.

It might be stated here that all cement used above the foundation except that in the walls, was made of Portland cement.

The lintels or carrying arches are 24 inches wide and 8 inches thick. They have a span of 10 feet and a rise of 1 foot.

The skew-back for the covering arches is formed of one course of brick laid on top of the lintels. The covering arches have the same span and rise as the arch which supports them, and are composed of 4 inches of brick and 4 inches Portland cement concrete.

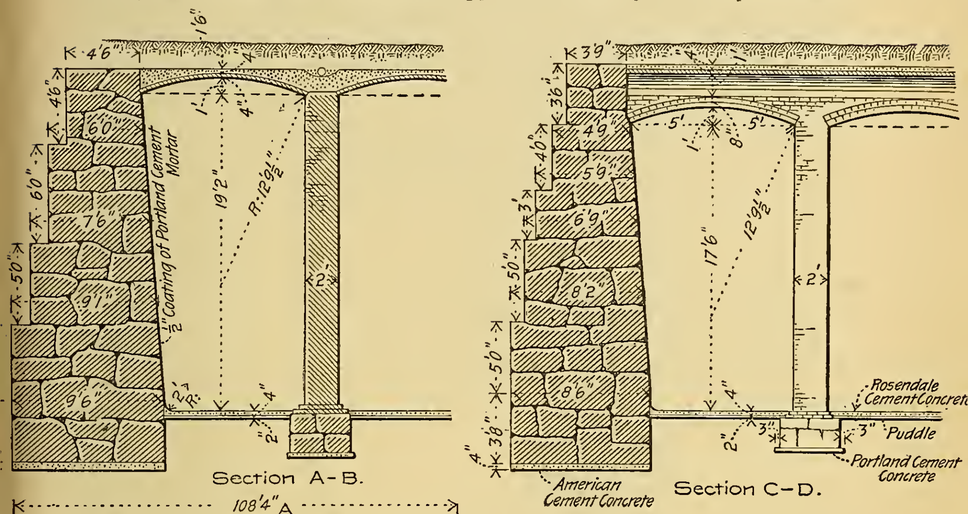
Suitable drains are provided to carry off all water from rain or snow which may reach these arches, and they are protected from frost by a covering of 18 inches of loam.

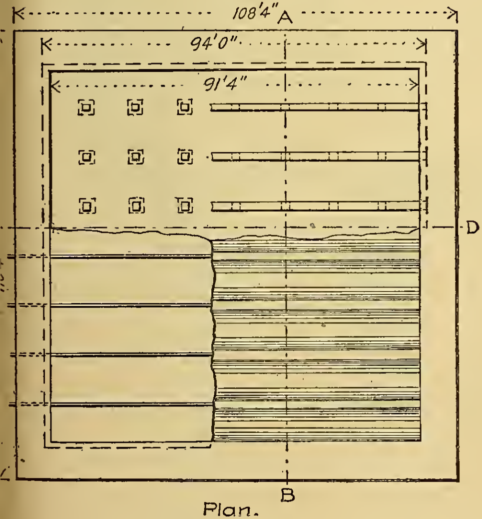
About 6 inches of clay puddle was placed back of the walls. The embankments were rolled or rammed in the usual manner. The bottom of the reservoir was first covered with 4 inches of clay puddle, and on this was placed 4 inches of American cement concrete. Great care was necessary not to mix the concrete and the puddle ; the concrete was successfully laid however, being placed in position with shovels and smoothed off with the same tool. No ramming as usually done was allowed, for fear of driving the soft clay up through the concrete. The concrete was also brought up around the sides of the walls and piers for a few inches.

As before stated, the inside of the walls were plastered with Portland cement. A difficult task in our case, as the reservoir was mostly in excavation and adjoining the open reservoir, consequently wholly below the natural water line in the ground. In such cases it would be well, I think, to keep the plastering in advance of the earth embankment on the outside. Perhaps later going over the walls with a thick wash of Portland cement. However the plastering was well done, as the later examination proved.

To determine whether or not the reservoir leaked to any appreciable degree, it was shut off last summer when nearly full, for 24 hours. After this length of time we could detect no difference of the level of the water, with the means we had for measuring. We concluded therefore, that the reservoir is practically tight.

The idea has occurred to me that in excavations where a good foundation for the pier could not easily be obtained, or there was danger of the bottom concrete being thrown up when the reservoir should be suddenly drawn down, the bottom could be an exact copy of the masonry of the top reversed.





COVERED RESERVOIR,

BROOKLINE, MASS.

F. F. FORBES, ENGINEER.

This form of construction would be a very safe one although more expensive.

During the construction of the work, an account of labor and materials furnished by the contractor was kept as far as possible, and while the amounts given are not absolutely correct, it is probable that they are not far

out of the way. I will now give the amount of work done, and the contract price for the same, immediately followed by labor and material account just mentioned. You will notice that the item of earth work is a large one. We unexpectedly found a bog hole in the bottom of the reservoir, which had been covered over with good material when the open reservoir was built, and was not discovered by the test pits. In consequence of this we had to borrow some suitable material for the embankments. This increased the amount of excavation by nearly 3,000 cubic yards.

Cubic yards of	earth excavation		7,480 at	$ .70	$5,236.00
"	stone masonry in walls	2395.4			
"	" under piers	51.2			
			2,446.6	4.50	11,011.50
"	brick work in Portland cement		173	19.50	3,457.35
"	brick work in American cement		142	18.00	2,556.00
"	concrete in Portland cement		280	6.95	1,946.00
"	concrete in American cement		145.5	5.45	809.32
"	puddle clay		47.3	1.50	70.95
"	bottom puddle		50	.60	30.00
"	puddle applied		38	.75	28.50
"	rock excavation		15	4.00	60.00
Square yards	cement plastering		824	.40	329.60
"	tar coating		1,018	.10	101.80
Feet of tile drain			714	.50	357.00
Extra work					140.00
					$26,134.02

Cubic yards of Roxbury stone measured in wall weighed 3,149 pounds.

Foreman	238 days,	at $4.00	$ 952.00
Masons	657	4.00	2,628.00
Engineers	321	2.75	882.75
Laborers (white)	1.358	2.25	3,055.50
" Italians	3,072	1.50	4,608.00
Double teams	203	5.00	1,015.00
Single teams	136	3.00	408.00
Derrick	396	3.50	1,386.00
Portland cement	598 bbls,	at 2.50	1,495.00
American cement	1,433	1.20	1,719.60
Stone			5,000.00
50 M Lumber		16.00	800.00
Sand and gravel			324.00
Brick			1,723.00
Grading			523.00
Teaming, derrick and incidentals			500.00
			$27,019.85

The reservoir has now been in use nearly one year. At an examination made last summer, when the water was drawn from it, everything was found in perfect condition. The reservoir appears to be a success in every particular.

The water drawn from it has been uniformly good, containing no trace of algae or fungi growth, and always of the same excellent quality which characterizes it at the pump well.

In closing the paper, I cannot help saying a word in favor of covered reservoirs for the storage of all waters obtained from underground sources, or waters which have been properly filtered.

This is the ideal way of supplying water to a city or town. A jug or bottle carefully cleaned, filled at a mountain spring and tightly corked could not give as good a water.

I hope that the number of covered reservoirs will increase in the near future, and that the people will insist that the same degree of neatness now required in the preparation of food shall extend to the water supply, and that they will not be contented to drink the water from surface supplies without filtration, in which frogs and numerous other animals and water plants, large and small, pass through all the phases of life, death and decay.

WATER SUPPLY OF WALTHAM.

BY

George E. Winslow, Superintendent.

(Read December 13th, 1893.)

The receiving, or filter, basin of the Waltham Water Works, from which the City of Waltham obtains its present supply, was built in 1873. Its location is about 30 feet from the old shore line of the Charles river, and, on account of the surrounding land and river, is shaped similar to a steam indicator card, covering an area of about 10,000 square feet. One end of it was left open and riprapped, with the intention of extending it at some future time. The depth of this basin in the center was about 8½ feet below the average surface level of the water in the river ; the bottom sloped upward from this point to the wall that surrounded it, at a grade of 1 foot rise to 3 feet run. It has no direct connection with the river, but was originally intended as a filter for any water that might find its way into it from the river. However, from subsequent experiments, it was found that there was very little water derived from that source, but most of the water obtained was that which was intercepted in its underground passage from the water shed to the river. During its construction, work was carried on both night and day, and continuous pumping was required, of between three to four million gallons in twenty-four hours.

From the north end of this basin, a stone conduit, about 56 feet long, 2 feet wide, and 3½ feet high, conducted the water into the pump well, which is built within the pumping station, of brick and stone, water tight, rectangular in shape, and 6½ feet wide, 20 feet long, 11½ feet deep. From this, the pump of one and one-half millions gallons capacity in twenty-four hours, originally obtained all the water that was used. In 1881 a second pump of the same capacity was put in, and the supply was found adequate to meet the requirements of the town at all times, until the summer of 1883, when it was severely tested by a drouth which continued through the summer and autumn. For sixteen consecutive days, when in a day's run of fourteen hours, there were pumped something over nine hundred thousand gallons, only one pump was available for the entire time, and it was even found necessary to run that at a reduced speed, during the last three or four hours of each day.

During 1886 it was fully demonstrated that the water supply must be increased, and the Water Board engaged T. Howard Barnes, Civil Engineer, to make surveys and plans for that purpose. Test pits and borings were made at a number of places, some as far distant as 1500 feet from the basin, which was the farthest that the slope of the surrounding land would allow. Several were placed along the shore of the river, and about 30 feet from it, which were used to ascertain the character of the soil and the depth to which it would be practicable to excavate. Levels, taken on the water found in

the pits, showed that the ground water fell with that in the basin, as the basin was pumped down, and that the difference in level was small. While the work was being done, the pumps were run for seven consecutive days, the basin pumped to the lowest point that the pumps would take water, and held at that point as nearly as possible. By these means it was found that the capacity of the basin was about 1,137,000 gallons in twenty-four hours, and, on account of the nature of the earth, it was found better not to extend the basin, as was originally intended, but it was recommended that the present basin be deepened.

In 1887 Mr. M. M. Tidd was called upon to visit our pumping station for consultation in relation to the proposed extension of our supply. By his suggestion a five inch pipe was driven, about 30 feet from our basin, and about 20 feet from the river, to a depth of 83 feet. While this work was being done, samples of earth were taken at different depths. His opinion was similar to that of Mr. Barnes', and he submitted a plan consisting of sixteen four-inch pipes driven to a strata of suitably coarse material, which the five-inch well had shown to be in abundance at 45 feet. The plan was to connect these four-inch pipes at the top, then with one, or both, of our pumps, and to use them to supply the city while excavating a well of suitable size, and, when found necessary, to pump from at other times. Nothing further was done in regard to an additional supply until 1891. At this time our Water Board, not being fully satisfied with the plans for an increased supply outlined by previous Boards, and realizing the difficulties and importance of an engineering undertaking of this character, hoping to get additional ideas, determined to employ another consulting engineer, and to lay before him, for review, the plans and reports already on file at their office, with a request that he make a minute, personal examination of the whole subject.

Mr. F. L. Fuller, of Boston, was chosen as a consulting engineer, and, after thoroughly examining the plans and reports of previous engineers and making a survey of the basin and surrounding grounds, he submitted a plan for deepening our basin. This plan was to build a well in the center of the basin, 40 feet in diameter, and from 15 to 20 feet deep, also to extend the suctions of our pumps to, and into, this well. This plan was adopted and the well was built during the summer. It was described by Mr. Fuller at one of our meetings last winter, and the description may be found in Volume VI, No. 4 of the Journal.

While the well was being built, the water pumped from it was gauged, both by the amount put into the reservoir and by weirs set so as to take all that was not used other ways. It is safe to say that our supply is increased from a minimum of 1,137,000 to fully 5,000,000 gallons in twenty-four hours, which is probably sufficient for the use of our city for a number of years to come. The building was accomplished at the expenditure of about $11,000, which includes the contract price, all charges for engineering, and other labor.

Our work to obtain a supply at the location being practically completed, it was thought best to protect it from the growth of algae, etc. Different ideas

and plans for this purpose were carefully considered, until this summer. At that time, Mr. F. P. Johnson, City Engineer, was called upon to perfect and make plans for covering the basin and well, which he did. These plans have been carried out, and we now have an abundant supply of excellent water, covered at its source, so as to exclude all light, and in a manner that is not in general use, but is perfectly satisfactory to our Water Board, and to all interested in work of this kind.

BASIN AND WELL COVERING OF THE WALTHAM WATER WORKS,

BY

F. P. Johnson, City Engineer.

(Read December 13, 1893.)

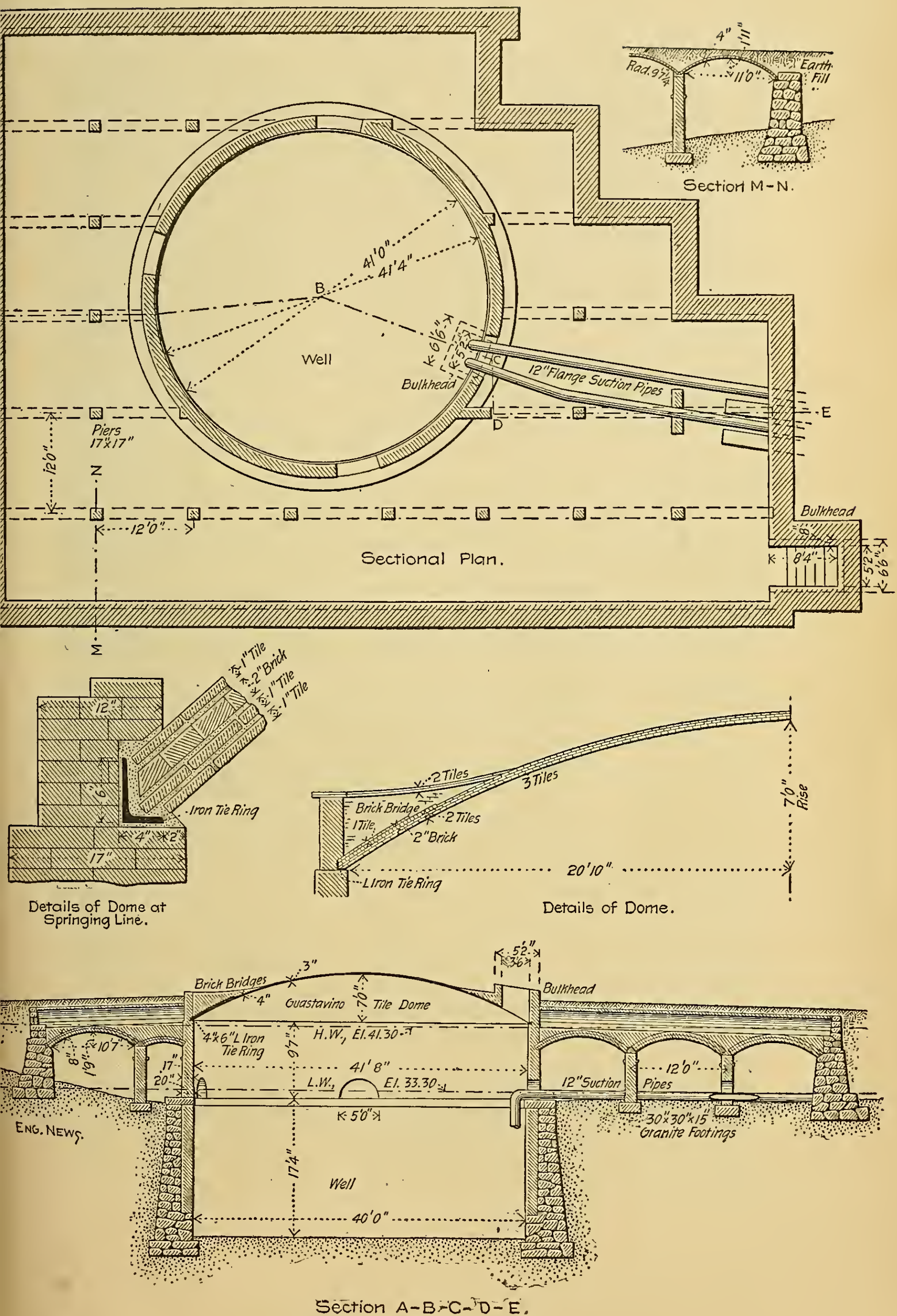
Mr. Winslow has spoken of the character of the ground at and immediately adjoining our pumping station. It may, perhaps, be in order to add just a word as to the peculiar situation of the well, by which its water shed is virtually enlarged, and which has perhaps much to do with the notable copiousness of its water supply.

What is known to geologists as the "Boston Basin," a gigantic sink hole or depression of the earth has its circumscribing fault (or seam in the rocks) passing just about under our well. The well being sunk in exceptionally loose drift material at the edge, so to speak, of the basin with ledge an unknown distance down while the ground changes in character a short distance to the north and west, ledge there being near the surface of a farm and wooded country of glacial drift not so much acted upon by moving waters.

Our conditions are somewhat exceptional.

Scarcely had I taken charge, last March, of the work of the City Engineering Department of Waltham when the Water Board requested me to prepare designs for covering the basin and well so as to exclude light, or for covering the well only and filling the basin and the board signified its desire to have the work completed by the first of June, if possible. Some three or four ready prepared designs were handed me, and each of the three members of the board privately gave me the outline of an idea which he would like to have developed. As requested, I prepared designs until some thirteen in all were considered. It is clear that the board had given the matter considerable thought, and it was therefore with some hesitation that I advised the design used and which was quite different from those previously considered.

The lowest price named in connection with the four plans first referred to called for an expenditure of $4,500.00 for covering the well alone, exclusive of walls, filling up the basin or other work, all of which items were to be done by the city.



BASIN AND WELL—WALTHAM WATER WORKS.

We soon developed the probability that it would cost more to fill the basin with earth than to roof it over, to say nothing of the loss of storage which such filling would involve.

My estimate of cost of the plan carried out was $5,854, aside from earthwork or stone walls.

Omitting these items the work has cost $5,187.50.

Everything included up to date the cost has been $5,846.50.

The stone and earthwork were omitted from the estimate because it was not known how much of the stone retaining wall around the old basin would prove to be in such condition that it could be made use of. When we came to do the work we substantially rebuilt the whole. There is perhaps $300 worth of odds and ends of cleaning up and loam spreading yet to be done, and there is in contemplation some landscape gardening; but which is entirely distinct from any connection with the work here described.

All materials save the Guastavino stuff, to be spoken of later, were purchased and all work carried out under the direction of the Superintendent of Water Works, Geo. E. Winslow, and I feel that great credit is due him for his management.

The covering will, I think, be readily understood from the blue prints of the design and more fully illustrated by Mr. Winslow's progress photographs, taken by him from time to time as the work progressed. [Blue prints and photographs were distributed.]

The basin is covered by ten inches of loam, overlying coarse gravel from two to twenty-six inches in depth (according to location) filled upon covering arches of 4″ brickwork of 23″ rise and 11′ 6″ span, sprung between lintel arches of brickwork 17″ wide and 8″ deep, with 21″ rise and 10′ 7″ span, carried by 17″×17″ brick piers which foot on granite levelers 15″×30″×30″.

The well in the centre of the basin is covered with a material which has been somewhat extensively used for flooring in fire proof buildings; but, it is believed, never before made use of in this country for out of doors construction; although it would seem to be especially well adapted to such purposes as this, being nothing more than a 1″×6″×12″ fire clay, corrugated tile, laid in Portland cement. It is a patented article controlled by the "Guastavino Fire Proof Construction Co.," of New York and Boston, which concern put in this portion of our work.

The only material in any portion of our cover, other than stone, cement or baked clay, is a 4″×6½″ wrought iron, forty-five pounds to the yard, tie ring, entirely bedded in and covered with cement and set to receive the tile of this well cover where it foots upon the well wall.

The economy for us in the employment of this Guastavino construction was that by its use we were able to avoid expensive centering.

Owing to the nature of materials of which our cover is built, we believe that there will be scarcely any expense for annual repairs and no chance for contamination of the water or foothold for growths which shall befoul it.

Some of our methods of handling materials of construction, etc., might perhaps have an interest; but I will not trespass further on your time except to answer any questions you may wish to ask on points not made clear.

DISCUSSION.

Mr. Brackett. I would like to ask Mr. Johnson if he can give us the cost of covering the well, separated from the cost of the entire work?

Mr. Johnson. That was done by contract; it was the only work done by contract. We raised the walls of the well proper up to four inches below the spring line of the roofing. The contract price for the Guastavino roofing, from this point up, including the tiling, iron work and everything, was $1,916.42.

Mr. Fuller. We have lately built a covered reservoir at Methuen, and it may be of interest, perhaps, if I give a few items of detail with regard to it. Instead of being a square reservoir like Mr. Forbes's, it is a circular one, very similar to the one which I described last year, which was built at Franklin. This is simply that reservoir with another ring of covering arches put on, of a larger diameter. This reservoir has a diameter of about ninety feet and holds about 1,000,000 gallons. All the excavation was done by day labor. The masonry wall was let out by contract at a $1.50 per perch for the laying. The stone was all taken from a neighboring locality, and paid for at the rate of $1.25 a perch.

The cost of this reservoir will certainly be less than $16,000; we cannot tell exactly yet because all the bills are not in and the work is not entirely finished. There was somewhere about 6,000 yards of excavation and about 1,200 yards of rubble masonry at $1.50 per yard. About 175,000 of bricks which cost on the ground $8.30, and the laying was $6.25. The cement cost about $2,400; the sand delivered on the ground, about $500; the crushed stone for the concrete in the bottom about $128; a road leading up to the reservoir about $112; the lumber for centering about $400; and the carpentry work in putting up this centering about $100. The method adopted for putting on the roof was perhaps a little different from the ordinary method. The centering was all put up before any of the brick covering was laid. The roof is eight inches in thickness, and the whole brick roof was put on in about six days. The whole reservoir was built inside of ninety working days. It cost about $16 to every 1,000 gallons of capacity.

The inlet and outlet pipe is fourteen inches, and comes in through the bottom, an extra thickness of masonry being provided at that point. The overflow pipe is a T put into the horizontal pipe and extending to the top. I expect we shall have an indicator to show the height of the water, so that there will be but little danger of overflowing.

Mr. Noyes. I understand the Brookline reservoir has been emptied after having been in service for some months. Do I understand from your description, Mr. Forbes, that the piers in the reservoir were brick, that is a brick surface?

Mr. Forbes. They were.

Mr. Noyes. How did you find the surface of those brick piers as compared with the concrete surface, if there was any difference? Was there any growth at all on them or indication of anything different from the concrete surface?

Mr. Forbes. I didn't see any difference at all.

Mr. Noyes. I might say that it has been something of a question, and one of a good deal of interest to me, whether there would not be a growth of some sort on the brickwork in a covered reservoir which would not be on the concrete. We haven't had occasion or opportunity to examine the inside of the Newton reservoir since it was built, so I cannot say what condition the inside is in ; but we have no reason to believe but what it is as good as when built.

This whole subject has been one of a good deal of interest to me from an engineering point of view, and we have before us to-day extreme types of covered reservoirs. We have the reservoir which has been described by Mr. Forbes, with piers twenty-four inches square and some nineteen feet high ; then the Newton reservoir, which has been referred to, where the piers are twenty inches square and some fifteen feet high ; and in their details they are very similar to each other, it may be the arches have a slightly larger rise in one case than the other. But we have the extreme case before us as presented by Mr. Fuller in the covered reservoir at Methuen, which is somewhat similar in design to the Franklin reservoir, as I remember it, and the piers nineteen feet high and twelve inches square. And we have the case brought before us to-day by Mr. Johnson, which is exceedingly interesting, of arches of four inches springing from piers seventeen inches square.

The point of extreme interest in Mr. Johnson's work is the use of the tile arch, the extreme thinness of the arch, which is some forty feet in diameter, the fact that the arch covering the portion of the filter basin outside of the wall is four inches thick, with no solid spandrel filling, and without apparently earth filling ; and, apparently, twelve inches of earth over the top of the four inch arch. On first looking at the plan it struck me as an extreme case of light work, and I should like very much if Mr. Johnson could give us a little more information as to the practical results, that is so far as stability goes as indicated up to the present time. It becomes us as engineers to design our work with sufficient stability to do the work required, and at the same time to save as far as possible the expense which may be wasted in making work of unnecessary dimensions. And if the designs as carried out by Mr. Johnson and Mr. Fuller show sufficient stability in a length of time, it shows us what we can do with good work, and how much we really can save for our clients. Of course it is an exceedingly delicate matter for an engineer to adopt these extreme conditions if he hasn't precedents of successful work to draw his conclusions from.

Mr. Johnson. If Mr. Forbes will kindly answer one question before I answer Mr. Noyes, I think it will bring out very clearly the underlying distinction between the two pieces of work. I would like to ask Mr. Forbes about how much cement he mixed at a time, and how many persons there were using from a mixture at the same time ?

Mr. Forbes. We mixed half a barrel at a time.

Mr. Johnson. Wet the half barrel at once ?

Mr. Forbes. Yes. We had four masons working in one gang, and it would last generally from fifteen to twenty minutes.

Mr. Johnson. What were the proportions ?

Mr. Forbes. Two of sand to one of American cement, in laying the foundation walls.

Mr. Johnson. That brings out the point I wish to emphasize, not as justifying or otherwise any work we have done, but as bringing out the underlying ideas in the two methods of construction, and the distinct intentions in making the work. I have no question as to the stability of any part of the work, not excepting the four inch covering arches, and there I deliberately omitted any filling in the spandrels between the arches, that is any filling by cement or concrete, though it is filled with gravel. And I did it with a view to economy, and also in consideration of the conditions under which we worked. Our work is a filter basin not a storage reservoir. We have a bank of material against it which has been in place a long while. The heaviest weight which we think can ever come upon it will be a crowd which may gather to view a boat race on the river. Now, in designing the work it presented itself to me whether to put the additional expense which would be required into concrete backing in the spandrels, in the valleys, or omit it, and I took the alternative of omitting it for the sake of saving expense, believing that we had ample strength. But I paid particular attention to mixing the cement, to the cement and the way it was treated. While the work was in progress I personally watched the mortar beds more than anything else. I insisted on careful selection of the sand and on all materials being mixed very dry, indeed during a portion of the work we heated our sand for the purpose of getting it dry. Then the cement was wet pailful by pailful, although there were from six masons upwards at work all the time, and I suppose the cement wasn't wet two minutes before it was in place in the work. The brick before being used were soaked in water and then allowed to drain for something like twenty minutes; and the amount of water was carefully gauged in mixing the cement. I think the brick certainly did not rob the cement of any water, and that the initial set of the cement would be a permanent set.

Something like three weeks after the work was completed, we tested it by having four men haul a 425-pound stone roller, with a tread of something like 20 inches over the well, and by examining the amount of bearing I estimated that that test was equivalent to a dead weight of about 1,700 pounds per square foot, under the conditions under which we applied it. By accident the roller at one place dropped about five or six inches on to the covering of the well without any disasterous result. Of course that applied a very much more severe test at that particular spot, and it certainly was not any stronger place than anywhere else. I felt therefore quite well satisfied with the work so far as we could test it then.

Mr. Noyes. Was this work laid in American or Portland cement?

Mr. Johnson. American Rosendale cement was used.

Mr. Noyes. Altogether?

Mr. Johnson. Altogether, excepting in the work of the Guastavino Construction Company. They used Portland cement without the special pains we took in the handling of the American cement. But I really believe we got superior results with our American cement to what they got with the

Portland cement which they used in the work. Their work is amply strong, I do not cast any aspersion on that, but our American Rosendale cement really gives us a stronger cement than they got with the Portland, and the reason is, I believe, the difference in the way in which it was used.

Mr. Noyes. What brands of cement did you use?

Mr. Johnson. We used Connolly & Schaefer and Hoffman; the greater portion of the cement used was the Hoffman cement.

Mr. Noyes. Did you use any different method in mixing your Portland and American cements, Mr. Forbes?

Mr. Forbes. I did not. The Portland cement was used on the brickwork only, and mixed in much smaller quantities.

Mr. Noyes. Was American cement used on the brickwork in the arches?

Mr. Forbes. No; all the brickwork in the arches were laid with Portland cement mixed in very small quantities, a pailful or so at a time.

Mr. Noyes. That is, you would use greater care in mixing the Portland than the American?

Mr. Forbes. We did, but at this time of the year it had got rather cold; and of course cement mixed in the winter time, with the thermometer about forty, will set very much slower than in the summer time when the thermometer is seventy or eighty.

Mr. Noyes. I should like to ask Mr. Fuller whether he used American or Portland cement?

Mr. Fuller. We used, I think, a mixture in the piers of American cement and Portland cement, but in the covering arches and in the stone work, and in the rubble masonry wall, the cement was entirely American cement. At Franklin we used Portland cement entirely in the piers.

Mr. Noyes. Was that on account of the design?

Mr. Fuller. No, we thought it would set quicker and that the piers would be less liable to swaying and distorting by getting out of plumb. By staying them we had very little trouble, and I don't think after the lintel arches were on there was ever any movement of the piers at all.

Mr. FitzGerald. I think there is one point in connection with these covered reservoirs that has not been fully dwelt upon, and that is the head of the water on the outside. When the reservoir is full and kept full for some time, the head of water outside must be about the same as on the interior, and as there are violent and sudden fluctuations in the level, when the water is drawn down, I would like to ask Mr. Forbes and Mr. Fuller if they have made any investigations on the question of the strength of the bottom to resist the upward pressure, if that has entered into their calculations? I notice that in both of these reservoirs there is no invert, and a very thin floor composed of clay and a thin lining of concrete.

Mr. Forbes. I remarked in my paper that when the bottom of the reservoir was built on material where the water was liable to get under the concrete, you might make the bottom like the top; that is you could spring arches from the piers, thus forming a bottom that could not be forced up under any circumstances, without forcing the whole roof up. Our reservoir

we built in an excavation in one of these clay hills like Parker Hill. When we first filled the reservoir we let it stand nearly full for, I think, ten days, and then we drew it off, and it was empty for a week or ten days, and I didn't see any indication of the water forcing the concrete up on the bottom. In fact the whole reservoir was practically tight; there was no water coming in anywhere. This summer, after the reservoir had been in use several months, we drew it off again, and we examined the bottom and sides carefully, and there was no indication of water entering through the walls or forcing itself up through the bottom. That is one reason why I say the walls of a covered reservoir should be very thick and very carefully made, because if there are spaces in the wall, when the water suddenly falls the flow through this wall might wash some of the clay, perhaps, back of it, and if it once began to wash the hole would gradually get larger and larger, and it would be only a question of time when the whole would tumble down. And having this in mind was one reason why I adopted a very heavy construction of the side walls, so as to guard against the water which may rise on the outside of the walls, perhaps, nearly as high as the overflow line, and then, when the water in the reservoir is suddenly drawn down and it is nearly empty, as our reservoir fluctuates from five to thirteen and fifteen feet every twenty-four hours, if there were pits in the bottom of the wall, or if there were pits back of the wall, or if there was any chance for the water back of the wall or in the wall or behind the wall to get underneath the concrete in the bottom and pass through, then it would only be a question of time when it tumbled down. That is one reason why we poured down barrel after barrel of cement and formed a grout around the stones, so as to be sure there couldn't be any holes or any chance for this water to run back and forth through the wall. I think that ought to be guarded against, or sooner or later it may all come down.

Mr. Fuller. I would say with regard to the Franklin and Methuen reservoirs, they were both built in material which was very hard, compact and homeogeneous, and I think it would be very unlikely the material would hold much water anyway. The filling behind the walls in both cases was thoroughly rammed and a great deal of time and labor was spent in both cases in making the backing thoroughly hard and compact, I don't see how it can pass much water. The Franklin reservoir was drawn off after it had been in use about a year and a half and carefully examined, and so far as I know there was no indication whatever of any rise on the bottom. The Metheun reservoir has not yet been filled, but I apprehend no trouble on that ground, and I see no reason why there should be.

Mr. Coffin. We have had an experience with the reservoir at Cohasset. It was covered with cement concrete six inches thick, with one inch of plaster on top; this covered the bottom, went up the sides and into the bank under the core wall. The water was drawn down suddenly one day, and the superintendent saw the bottom beginning to rise. He went into the gate house and got an ax and went down and cut a hole in it, and the water gushed up and the bottom went down. The reservoir was built in material which

seemed to be almost absolutely impervious to water, but in drawing it down so suddenly I suppose there was a pressure upwards on the large surface on the bottom. I presume it is different in these covered reservoirs, where the bottom is divided up into small squares by the piers; I don't know just the construction of those piers but they probably have some effect at least in shortening the span and holding the bottom down. I mention this as one instance where the bottom of the reservoir came up from the pressure of the water.

Mr. FitzGerald. There is one other matter I want to refer to. I am not quite sure as I heard distinctly, but I thought I heard one member say his experience in some of his work had led him to believe that the American cement had given better results even than the Portland, and he mentioned certain brands. As this is so entirely contrary to all engineering experience, I hope further details will be given to us, so we may become thoroughly acquainted with the foundation for this experience as it certainly ought to be of a great deal of value if founded on absolute experiment and fact.

This large well at Waltham is an extremely interesting one. I have for some years taken an interest in these large wells, and from time to time have seen them in process of construction; and particularly in the west they use a great many of them, both for public water supply and for furnishing railways with water to fill their locomotives. Nothing has been said here today about the method of sinking these wells. I have seen wells from twenty to forty feet in diameter, sunk from thirty to forty feet in depth, and varying in cost from $20,000 to $2,000, depending upon the method of putting them down, and the amount of care and thought expended in that direction. One of the largest wells I know of, and one of the most remarkable, and one of the first ever built in this country, is in Prospect Park, Brooklyn. That is a brick well fifty feet in diameter, and sunk to a depth of sixty feet. It was built on a curb and sunk that depth by excavating very carefully in the interior; and that is the method generally employed, where economical construction is provided for, I think. Of course there are places where, perhaps, it is not possible to do it. I thought it might be of interest to call the attention of members to this matter of sinking. If any of you are going to put down large wells, that is one of the most important things to study in the beginning.

Mr. Johnson. I think Mr. FitzGerald has reference to me in speaking of Portland and American cement. I perhaps did not make myself clear. I did not wish to be understood as making any statement that American cement, used under the same conditions, is superior to Portland cement. What I did intend to say was this, that the Company using the Portland cement in this case, mixed their cement and wet it some little time before it went into their work; and while nominally mixed two to one, I think really it was a good deal nearer three and a half to one. They did not measure the materials as they went in, as we did. Our cement was used with brick which were very damp, and yet not running in water, and before the cement had been wet more than five minutes at the outside, it was in place on the brickwork. The

Portland cement had been wet for some little time in many instances before it was used in the work, and their tiles were used entirely dry. I permitted the work to go in in that way because of the guarantee they gave us that the work should be submitted to a test which we approved, which it amply stood, and further, because I believe that ample strength was had by that use of the cement. Perhaps that answers Mr. FitzGerald's question.

Mr. Walker. We do all our business at Manchester open and above board. The reservoirs are all open and the saloons are all open. (Laughter.) We are about to build a reservoir in a solid ledge, and I want to ask if any engineer who can tell me how to make it tight. I understand there is some difficulty in getting a tight reservoir in rock where there are seams

Mr. Tidd. Mr. Walker seems very anxious to know how to fill up the cracks in a ledge, and to be afraid that his reservoir won't be tight. I should say with the saloons all open it might get tight. (Laughter.) A reservoir in solid ledge is rather expensive, perhaps, but my idea of an ideal reservoir is one which would be solid masonry, and if the masonry is properly put in, it can be made tight. I suppose a reservoir in any ledge, and I never saw a ledge that wasn't seamy, can be made tight with proper lining. The lining probably would have to be cement or clay, and cement would be better. A friend of ours built one in Woburn in a ledge, and he had some difficulty in making it tight, but he afterwards accomplished it by lining it with clay. When they first commenced to pump into it, they got it about half full and they couldn't get the water any higher ; so they drew it down and lined it inside with clay and it has been all right ever since, about twenty years. I don't think Mr. Walker will have any difficulty if he goes to work in the proper manner.

Mr. Walker. How thick should the lining be on the bottom ?

Mr. Tidd. They didn't put any on the bottom, but on the sides they put six inches of clay.

THE CONSTRUCTION OF RESERVOIR EMBANKMENTS,

BY

LUCIAN A. TAYLOR, Civil Engineer, Boston, Mass.

[Read Jan. 10th, 1894.]

The construction of Reservoir Embankments, the subject of discussion to-day, is one of great interest and importance to engineers, water-works officials, and the public generally.

The pressure exerted against an embankment holding, we will say, forty feet of water, is something enormous, being more than twenty-five tons for each lineal foot of embankment. To resist this pressure under all the varying conditions of weather, the rapid rising of the surface of the water in the early spring, at a time when the embankment or the exposed portion of it is in its weakest condition through the action of the frost, requires good material and plenty of it.

An earthen embankment, whatever the material, clay, loam, sand or gravel, will be penetrated by the water in the reservoir to a certain depth, depending on the depth of the water and the nature of the material used.

It would be very interesting to know to what depth this penetration extends under different circumstances and with different materials in the embankment.

The effect of the resistance of earth in an embankment, is to retard the flow, and the pressure is exhausted. The water is fatigued and loses its force. In the case of fine material mixed with clay or even fine sand, when the particles are small, the penetration of embankments, the writer believes is not very great.

Every fine particle of material occupying a space between coarser particles has its effect in the resistance it offers to the flow of water.

As each location, each embankment, and piece of work to be done, has its different local conditions, no set rule or formula can be made to determine the minimum safe thickness of an embankment. Each individual case should be referred to a practical and experienced engineer.

Practically, the writer believes it is much easier to build a water tight embankment, than a water-tight masonry or cement concrete wall, each having a thickness as ordinarily designed for reservoir dams.

The writer does not now call to mind any instance of an embankment being carried away by percolation through the body of the embankment.

Almost invariably, the leaks and breaks take place along the line of connection with the original ground or foundation, or in contact with stone or concrete masonry, or cast iron pipes, all substances with which it is difficult or impossible to make a bond or connection with an earthen embankment.

Most earths in their natural position are to a certain extent porous, or have viens, and fissures and water ways through them.

It is also true that most earths may be made into a water-tight embankment many times by the simple rehandling of the material.

The shrinkage and consequently the increased compactness of all earths, as we ordinarily find them, is largely, if not wholly, due to the closer and more perfect mixing of the fine and coarse particles of earth.

We have a good example of an earth embankment in the reconstruction of the dam on Lynde Brook in Leicester, a storage basin of the Worcester Water Works.

In the spring of 1876, a break was made in this dam about 200 feet in length, the result being, the emptying of the reservoir of about 660,000,000 gallons of water, and a large amount of damage to property in the valley below.

It is not the province of this paper to discuss the causes of the break, but simply to give a brief description of the manner of building the embankment, it is well to say, however, that it was no fault of the material or construction of the embankment.

The sections show an embankment fifty-five feet wide on top, it having been the intention to raise the dam five feet at some future time. The up stream slopes are two horizontal to one vertical, and down stream about two and one fourth to one. The essential feature of the new work was the building of an earthen embankment, through which was a clay puddle wall.

The greatest depth of water in front of the dam is about forty feet. The top of the dam is about four feet above the wasteway, and the embankment 59′ 3″ in the highest place.

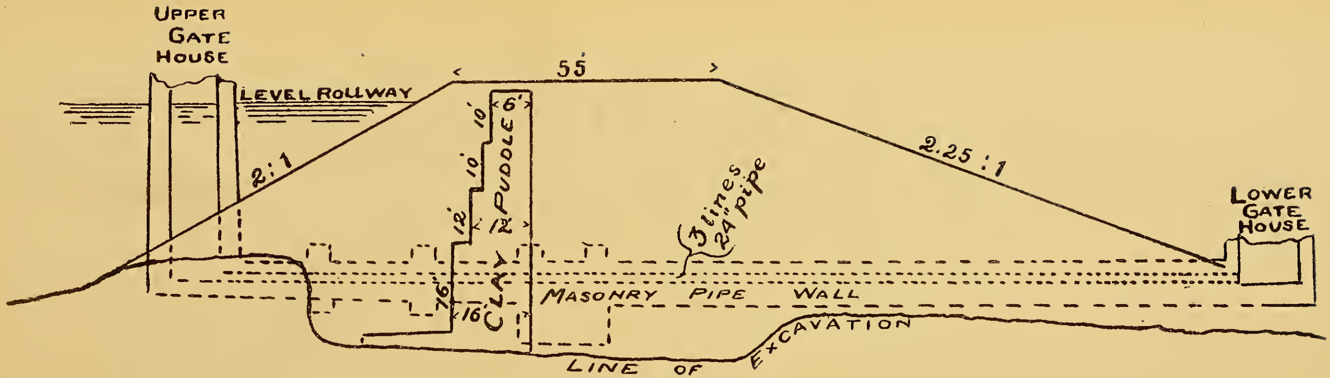
Down stream from the top line of the lower slope no pains were taken as to the quality of the material except that it was not perishable. Stones, bricks and much coarse, washed material were placed in the lower slope.

The clay puddle wall, the up-stream face of which is on a line with the top of the inner slope, was built in the following manner : The selected material was put on in layers six inches in thickness. The large lumps were previously broken, and stones of more than two inches diameter were thrown out. After each layer was in place it was cut with twelve inch garden spades in cuts not exceeding one inch in width. It was then cross-cut in the same manner.

The thickness of each layer after spading was about four and one half inches. This process of spading cut and cross-cut each layer twice.

Where the clay puddle came in contact with the natural ground in the lowest parts of the foundation, and where the greatest care was exercised, pea gravel was mixed with the clay, from fifteen to twenty-five per cent. of gravel being added. The size of the gravel used was from one fourth to three fourths of an inch in diameter.

At the time the breach was made in the dam, a pit was excavated in the natural ground from fifteen to thirty feet in depth, sixty-three feet in width, and one hundred feet in length, or cross-section of the dam, that was cleared of debris in the reconstruction.



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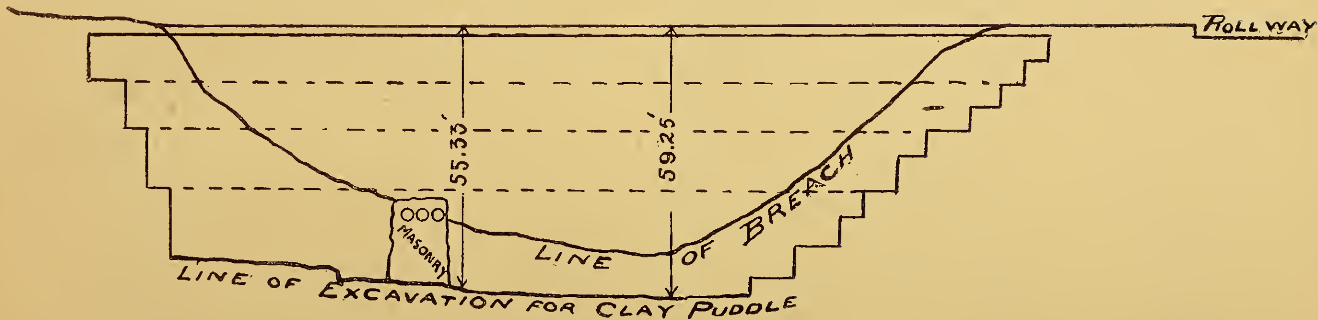


LONGITUDINAL SECTION.

LYNDE BROOK BESERVOIR DAM, WORCESTER WATER WORKS.

The bottom of this pit was from twelve to fifteen feet below the bottom of the reservoir in the deepest place, and from fourteen to seventeen feet below the bottom of the supply and waste pipes, which were laid in a masonry wall imbedded in the natural ground on one side of the pit.

In this pit the width of the clay puddle wall was from thirty to forty feet on the bottom, or in contact with the natural ground. It also enveloped the pipe, and cut off walls of which there were six, on sides, ends and one foot above the top.

At this elevation, or thirty-five feet below the top of the embankment, and thirty-one feet below the crest of the wasteway, the wall was made a uniform thickness of twelve feet. The thickness of the wall below this elevation, except at the points mentioned, was sixteen feet.

The clay puddle was carried to a point two feet below the top of the dam, at which elevation it was eight feet in thickness.

The difference in thickness of the wall was made by horizontal steps, on the up stream side of the wall, also all excavations, steppings, and toothings, into the natural soil and the embankment of the dam, were made by horizontal and vertical excavations or steps.

The embankment on the up stream side of the puddle wall and also that on the down stream side to the top line of the lower slope, was built of excellent material, put on in from four to six inch layers, rolled with a heavy roller, and at the ends and other points not accessible to a roller, thoroughly rammed.

The material for the embankment was, in fact, only slightly inferior to that used in the puddle wall. With the exception of the points mentioned, the puddle was used in its natural mixture and probably contained about one-third pure clay.

During construction, the embankment was kept at least six inches higher than the puddle wall.

Great care was used to get rid of any pools of water or excess of moisture by dipping it up in buckets, and also by exposure to sun and air before working upon it again.

This embankment has now been built seventeen years, and there is not the slightest indication of any percolation through it. Indeed it is the belief of the writer, that it is doubtful if the percolation from the reservoir even reaches the puddle wall.

It is a somewhat unusual condition to build an embankment sixty feet in height and less than 200 feet in length. It is believed, however, this was accomplished with practically no settlement in the embankment, and consequently no breaking of the material at the points of contact with the original ground and old embankment.

Whether it is wise or economical to build a dam of earth entirely, must depend upon the circumstances or the kind and amount of materials at hand, and the ease with which they can be procured. There is, however, no doubt that perfectly water-tight embankments can be built, and of ordinary material, perhaps the most important essential being a firm water tight foundation.

DISCUSSION.

Mr. Darling. I would like to ask Mr. Taylor whether he would recommend building a dam out of earth, with no center core?

Mr. Taylor. It would depend entirely on the circumstances. It would be a question of expense and the kind of material you found.

Mr. Darling. That may be right, perhaps, in places where they don't have animals that bore through dams. But in the case of the dam which was built at Leedsville, it was said at the time it gave way it was a musk-rat that bored through. Now, wouldn't that be likely to occur in the same way with any dam, if there wasn't a center core?

Mr. Taylor. I don't believe it would be possible for any animal we have in this country to bore through the dam I have described, or one like it. I have never known an instance of that kind. There is a reservoir of 160 acres, and it is out in the country, I don't know whether there are any musk-rats there, but I don't think it will make any difference whether there are or not, and it has been in that condition seventeen years, and is just as good a piece of work as can be found in England. In this particular case, the embankment is excessively heavy, but I don't think there is the slightest danger from musk-rats in material of that kind.

The President. We would like to hear from Mr. Freeman.

Mr. Freeman. Mr. President, I did not come here expecting to speak, but rather to listen and learn. However, continuing in the line of the suggestion of Mr. Darling, which Mr. Taylor has just answered, I would like to allude to an experience, of which Mr. Tidd can tell us something, where another kind of an animal tried to ruin Mr. Tidd's reputation. This was not a musk-rat, but was a woodchuck,and before his operations were discovered, he had dug his hole 12 or 15 feet into a reservoir embankment which had been built in a very thorough and compact manner.

It seems to me that a core wall is always a good thing, and that in almost any ordinary case it is worth its cost. There are cases, of course, where its cost would be prohibitive, and there are cases where the material is of such an excellent nature that one is justified in getting along without it. But I will confess myself to having a very strong preferance for a core wall, both as a preventive against the working of musk-rats and of woodchucks, and as a means of making the embankment tight; and also as a means of causing the destruction of the embankment to take place gradually in case the water does penetrate it.

As to one other statement of Mr. Taylor, that regarding the relative tightness which could be secured with a core wall or with an embankment without a core wall, it seems to me that depends entirely on the material used. In many cases where you have what here in New England we call "pudding gravel," you can unquestionably make the bank most admirably tight with that alone. But, on the other hand, if you have a loose sand, as in one case with which I have had some experience recently, where there is no gravel that will puddle, and no clay within a radius of several miles from the point where

it is desired to build a dam that may ultimately be some 40 feet high, nothing but pure, loose sand ; in a case like that it would be almost impossible to construct your bank out of that kind of earth so that it would be anything more than a gigantic filter when you got through, unless you put something else in to make it tight, or brought material at great expense from a distance for a puddled core or lining.

Now, you can unquestionably build a bank of pure, loose sand and get that bank into a very tight condition in the course of time, when the stream carries any considerable quantity of sediment. There is along the manufacturing canal at Nashua, a high bank composed of nothing but pure, loose sand, not a particle of clay in it, or within several miles of it, and this manufacturing canal has been standing there now for the past 60 years. Skirting the bluff, the canal 9 feet deep, the water level 20 to 30 feet above the outer toe of the embankment, built wholly in pure sand through which water naturally percolates freely. The canal was small in the early days, and has been gradually enlarged, and though undoubtedly a great deal of water was lost by percolation at first, the canal has in the course of time become satisfactorily tight.

We may have that kind of a bank on a running stream, or on a stream that carries a moderate quantity of suspended matter. But, on the other hand, if you were to build an embankment for a reservoir which would practically store the whole annual flow of the stream, the water thus being infrequently renewed, or if you built such a bank where the water was very pure and the amount of clogging material in the water was very small, you might have to wait a very great length of time before you could get a bank built of pure sand into a perfectly tight condition.

I have had some experience in building banks of very pure sand, and in noticing how they could silt up afterwards ; and it simply amounts to building a bank that is not much better than a filter in the first place, and then waiting for this filter to become clogged.

One point, I think, to which sufficient attention has sometimes not been given, when trying to get perfectly water-tight core walls, is that stones have been used of rather too large a bulk. I think that in France, it is generally recognized that for the best work in the shape of a water-tight masonry wall, no stone should be used larger than one or two men can lift ; the same statement has been made by some of the best engineers in this country, that is, on a wall of that kind you can get much tighter work by hand work than by derrick work. I did not come expecting to speak on this subject.

Mr. Tidd. Mr. Chairman, I can say, as Mr. Freeman said, that I came here to get information from others rather than to say anything myself. But speaking of reservoirs, on general principles I should say an ideal reservoir, according to my ideas, would be one of solid masonry. There is one thing sure about that ; it never can wash away. But, of course, wherever we build reservoirs we have to be governed largely by the material which is at hand to make them. I have built them of solid earth, without any core wall at all, where I could'nt get the material very easily to make a core wall of, and so

far they have been a success. But the earth was good enough to make a puddled wall of all of it, so in fact it was really a puddled wall. Mr. Freeman has alluded to one case, where I had good material to build in. It was in Maine, in Lewiston, where we had as good material as could be had anywhere, a sort of clean gravel mixed with clay which was in fact nearly as hard as stone, and in that case I used a brick priming wall. The embankment was 15 feet wide on top, the inside slope was one on one and a half, the outside one on two, and two years after the work was built we found a hole there made by an animal that we supposed was a woodchuck. He bored a hole in so far that we could run a pole in 16 feet. That was as solid earth as ever I saw put in a wall, and as solid as we could ever put down in a puddled wall, and it seems an animal did bore into that. But of course he could never have got through the brickwork ; that would stop anything.

As I said before, my idea of an ideal reservoir would be one of solid masonry, and it can be made tight, and when it is once made tight it is there forever. But we can't always afford to build a reservoir of solid masonry, and the next thing to it is to have a core wall of masonry, which I should construct every time when I could get the material. I had occasion to build a reservoir once in Prince Edward Island where all the stone on the island is the poorest, softest kind of red sandstone in layers, drift rock all through, fissures between the layers, and all the stone we could get to use even for the rip-rap on the inside of the reservoir we had to bring by vessel twenty-four miles across the Northumberland Straits. So of course in that case we could not very well afford to build a masonry reservoir. So I endeavored to make it of a puddle of clay which they had there, which was so poor that it broke through many times into the fissures of the rocks and away down the hill. But after a long time, by using cement and concrete in those places where it could be done, we succeeded in getting it tight. To give you an idea of the material used, I will say that near the reservoir, 50 or 60 feet below it, was a quarry where a man got out sandstone. Of course they used it as stone, for it was the only kind of stone they had there, and they used it in buildings. He complained that the water from our reservoir filled his quarry, and he brought suit against the city for damages. While the case was pending, or rather before he brought the suit, immediately before he brought it, while he was complaining to the authorities, I sent a man down into the quarry and he drilled a 2-inch hole down 10 feet, and that let the water all off straight down through the bottom of the quarry, very much to the owner's chagrin. (Laughter.) I merely mention that to illustrate the character of the material there.

There is one thing I have always studiously avoided in the construction of a reservoir, and that is the putting of anything like a pipe through the embankment. Of course we are obliged to lay a supply pipe in through the embankment, and in all those cases no matter what the material is, I have made it an invariable rule to lay a core wall across the pipe; even if don't go clear around the reservoir, I lay it far enough to make it sure nothing will get along the pipe; and the pipe which goes through the wall always has a

collar or flange cast around it, two or three inches high and perhaps two inches wide, and that I take very particular pains to bed solid in cement. When that is done thoroughly there is no danger of the water following the pipe. I have had occasion in the construction of dry docks to build coffer-dams, some quite large ones, where we were obliged to run timber braces through the filling of the dam. In all those cases I have taken pains to nail a cleat around the timbers so that there should be no passage along the timbers for the water to follow. Water is very insinuating in its pressure. It is not only the pressure, which Mr. Taylor has referred to, it is all that he speaks of, but it has also a tendency to bore small holes. It is insinuating, and if there is a crack ever so small, it will find its way through it and enlarge it, if it once finds its escape on the other side. I remember building a reservoir once in Nova Scotia, on a hill, where we had very nice clay indeed, and there we built a puddle wall, and puddled the bottom of it. Stone was too expensive to use there, and we built a carefully puddled wall entirely around the reservoir. It was on a side hill so steep that the bottom of the reservoir at the lower corner was higher than the natural surface of the ground, and we had to build quite a berme on the outside to support that corner. After the reservoir had been built and we attempted to fill it, we found a stream, which might have been an inch or an inch and a half in diameter, made its appearance at the lower corner, much to the terror of the contractor. He immediately wanted the water drawn out of the reservoir, which was then about half full. I insisted upon its being left as it was, and berated him for leaving some place in the wall without having been properly puddled. He claimed he had done it all propeily, but I claimed the stream was sufficient evidence he had not. We kept the reservoir half full, (it was one we pumped into,) I think, for four days, and at the end of that time the leak stopped itself. It was simply a place where there were some lumps of clay which he had not properly puddled, and the water in its passage through it had finally dissolved the clay and had filled the spaces ; and the reservoir stands there today, I think it has been there some seven or eight years, perhaps ten years, and is absolutely tight. It was simply that it wanted more thorough puddling. I have no doubt there are many gentlemen here who have had experience which would be interesting in that direction.

I remember a case in a dry-dock where the water blew up from underneath, and came up in a stream 6 or 8 inches in diameter. Of course that was something which was very hard to handle, but we did finally stop it by piling it with round piling, 20 or 30 feet deep, and capping it across the top with two layers of 12×12 hard pine, bolted down to the piles. That stopped the water coming up there, though it may be it forced it out somewhere else, but anyhow, it didn't trouble us afterwards.

But I suppose one of the worst spots in a reservoir is the discharge pipe out through it, or the inlet pipe, unless the work is most thoroughly done. I was connected with some works in Wisconsin one time where we built a reservoir that was filled by an artesian well which had on it something like 40 feet head, and from the reservoir we pumped the water to a standpipe. In

that case, of course, there had to be an overflow, and we built the overflow down through the bottom of the screen well. The bottom of the well was put in in solid concrete, and the pipe was made with a flange on it, as I have said I always do. It was set vertically and the top of the pipe was cut off at about 4 to 6 inches below the full level of the reservoir, and went down vertically, passed under the bottom and out into the river which was near by. The water, when it rose to the top of the pipe, went down vertically through the pipe. There was no path there for water to find its way through the sides, certainly, and we never had any trouble from it. That reservoir has been built about five years, and it is tight today, and in good shape. As I said before, Mr. Chairman, so I will say again in closing, give me masonry every time ; and if I can't have the whole reservoir of masonry, I will have at least a masonry wall around the entire artificial embankment, and far enough into the natural earth to absolutely secure it.

The President. We should like to hear from Mr. Noyes of Newton.

Mr. Noyes. Mr. President, I do not know as I can add very much of practical interest to what has already been said, unless it be to refer to a description recently given me, of work successfully executed by an engineer, who had in his practice been obliged to adopt plans and methods for accomplishing desired results at the least possible cost. I was specially interested in the results he claimed to have obtained.

He stated he had built reservoir dams or embankments 16 or 18 feet high with fine sand, such as is found in the sand dunes so common on Cape Cod.

He described a reservoir embankment about 16 feet high, he had built with slopes one and one-half to one. The material in the embankment was fine sand and the slopes were covered with the turf taken from the ground. There was no appreciable infiltration or leakage of water through the embankment, and the reservoir was used for a number of years for storing water. A section of the embankment was ultimately carried away, the break being caused by the flow of water through a hole made by a woodchuck. He repaired the break by filling the hole or section carried away, with the material washed away or material like it and then facing the inside slope with a clay gravel, commonly known as hard pan, put on in thin layers with a total thickness of two feet. All stone above two inches in diameter were carefully picked out and the layers compacted by spading rather than by rolling or tamping. This facing was covered with four inches of broken stone and a layer of broken stone rip-rap 12 to 14 inches thick. He did not think it possible for any animal to bore through the covering. Water had been stored in the reservoir since the repairs were made and the embankments showed no weakness or leakage through them.

He is now engaged in building an embankment about 16 feet high and 2,000 feet long, the plans and details for and materials used in the construction of the embankment are similar to those adopted and used in the embankment just described. He found a more compact embankment could be made if the material used was not wet but slightly damp, and no water used while rolling the layers as put on. He had examined, by cutting through the embankment

constructed without the use of water, and found the material more solid or compact than the material in embankments upon which water was freely used. This opinion coincides with statements made in a discussion upon this subject, heard at a recent meeting of the Boston Society of Civil Engineers, and with some of the suggestions made here today. From his experience in building reservoir embankments he preferred a fine sand to other material.

While my experience in constructing, and observations made of reservoir embankments constructed by others, lead me to somewhat different conclusions as to the best material to use, the engineer I refer to is to a certain extent right, that is, the material should be perfectly compact, have no voids, will not expand or swell if wet or contract if dry, and will not be readily taken up if water gets access to it and be readily washed away.

By the use of a fine sand all of the conditions except the last are met and the efficiency of an embankment constructed with this class of material depends upon the measures adopted to keep water from acting directly upon it. One of the greatest difficulties met with in the discussion of questions involving the use of terms describing the various forms of glacial drift, surface or sub-soil loams or moulds or even stone is from a lack of uniformity of nomenclature used in different parts of the country or even among our own members.

Mr. Brackett. Mr. Chairman, it hardly seems to me that sand is a proper material for building a reservoir embankment, certainly not in a great many cases. It might be suitable for building an embankment on a stream in the woods, or in some location where no damage would be done if the dam were carried away, or where there would be no damage done by any leakage through it, as in the case of the canal spoken of by Mr. Freeman. There would be liable to be a large amount of percolation when the reservoir was first constructed, which might afterwards be stopped by silting up. But surely in building a distributing reservoir for a city or town, as such reservoirs are usually built on hills, I don't think it would be proper construction to build the banks of sand.

In regard to the wetting of the material, I believe, with Mr. Noyes and Mr. Freeman, that the less water used the better. But in the case of the hard pan which we have in this vicinity, it would be in a great many cases almost impossible to make a compact bank without the use of some water. The hard-pan breaks up in lumps from 3 to 6 inches square, and it is very difficult to pulverize them, especially if they get a little dry and hard. But by using as little water as can be used to moisten the material, and then applying the material in layers not over 4 inches in thickness, and thoroughly rolling it, I believe you can obtain a very compact bank. That was the method adopted at Fisher Hill reservoir, and it might be interesting to know that the watering and rolling of the material placed in the embankment there, about 80,000 yards of material, cost about 2 cents a cubic yard, and the work was very thoroughly done.

Mr. Noyes. I might add to what I have said, in answer to the criticism of Mr. Brackett. The engineer to whom I have referred was of course limited

as to the amount of money he had to expend, and I presume also he did not have the conditions which Mr. Brackett mentions, where there would be great damage done or danger to life from the giving away of the embankment, although he spoke very positively as to the efficiency of the work. I questioned him closely as to the probable filtration of water through the banks. He said that in no case had he found any evidence of filtration. I asked him if he did not in gauging or keeping the flow of the stream, or in any way, find that he lost an appeciable amount of water, enough so he could determine it by estimate. He said he did not, and had had no case where moisture had appeared below the bank, or where he thought there was any percolation.

Mr. Tidd. Mr. President, theory is one thing, and practice is quite another oftentimes. Now, I undertake to say that it is impossible to make a bank of clay or ordinary hard pan absolutely homogeneous and put it in dry. I don't believe it can be done. I have tried it several times and have found it needs a certain amount of water to dissolve it, as Mr. Brackett has said, especially any hard lumps. And the difficulty we had with the reservoir in Nova Scotia, where we had a stream come through the corner, was simply on account of the hard lumps which had not been wet enough to dissolve them and make the homogeneous with the rest of the material. Now the fact that you can pack dry material into a box and ram it down hard, and make the box hold more than you can if the material is wet, does not demonstrate that you can make a dam or reservoir embankment of dry material and have it tight; because you have the walls of the box in which to confine your material so you can pound it down solid. But if you take dry material and put it in a bank and undertake to roll it, as your roller passes along it will push the material ahead of it and force it out at the sides. I have tried it several times, times enough to learn that. If there is moisture enough to hold it and pin it down, your roller will then pass over it and put it in place, but if there is not the roller will push it ahead as I have said.

Speaking of sand embankments, I had occasion once to inspect a reservoir built at Platsmouth, Nebraska, at the mouth of the Platte river, by Mr. J. D. Cook, who has the reputation of being as good an engineer as we have, and it was built entirely of loose sand which was scraped up on the river flats in dry times. The idea was to build a settling reservoir, and to pump the water from the river into it to settle, the water to be pumped from there into a higher reservoir for distribution. I have no means of knowing what the result finally was, for at the time I saw it the river was low, and at times of high water it must flow within two or three feet of the top. There was nothing whatever used but sand, and I have some curiosity to know how the thing finally came out. It was built by a man whose reputation is as good as that of any engineer in the country. Of course the river is full of dirt and silt, and I have no doubt if the banks stayed there long enough to have this material filter into them they might be all right; but my idea of the thing was that the first freshet in the river would sweep them all away like a lump of sugar.

I have seen places on the banks of the old Middlesex Canal, which was used for fifty years, where they were built of loose gravel, and when they have been cut through in sections there appeared to have been no effort whatever made in their construction to make them tight, and yet they carried the water; but it was the water from the Concord river which carried with it a large amount of sediment, and the probability is that had filled the interstices and made the banks tight. I can easily conceive how that might be. I think we had a little experience of that in Brookline, as Mr. Forbes will remember, when they were short of water once at their filter gallery. They cut a trench along from the river parallel with their gallery, and led the water into it thinking it might filter through into the filter gallery. But that trench, as I remember it, declined to pass water through in about four or five days, and we had to rake the surface over every few days in order to get the water through. The material that came in the water of the Charles river, and which collected in the filter embankment, plugged up the bank so the water would not pass through it. The material that we raked off the bank resembled felt in appearance, and after it had been raked off it would allow quite a large flow of water for several days, and then it would close up again. That, I suppose, is the secret of the success of these embankments made of sand. If the water is clear and pure, like subterranean water, with no sediment in it, I doubt very much if a sand embankment could ever be made to hold it.

Mr. Darling. Speaking of the percolation of water through gravel, which my friend, Mr. Freeman, has referred to, I would say that in building what is known as the Diamond Hill dam, the ledge on each end of the artificial part comes up level with the top of the plain, as we call it. On the west side is a flat, level plain, consisting of material which is mostly coarse gravel and white sand. This plain extends from 400 to 800 feet behind the dam, and then comes the abrupt falling off down to the meadow bottom some 40 feet below. When we filled the dam to its full capacity there was a percolation that extended up the slope about 10 feet above the level of the meadow for some 400 feet in length, it wasn't of a magnitude that alarmed us, because of the thickness of earth behind the dam, and extending beyond the face of the dam some 200 or 300 feet. This percolation has kept receding since the dam was built, until now we cannot see any on the slope, showing that the silt, or whatever may have gone in there, has practically made the earth perfectly tight. I simply speak of this as a practical illustration of the effects of the filtration of water through earth embankments.

Desmond FitzGerald. The subject of reservoir embankments and earth dams has recently received a large amount of attention. It was discussed before the Boston Society of Civil Engineers in September, 1893. Having lately designed two high embankments for the storage of water for the City of Boston both between 60 and 70 feet in height and having devoted some time to the study of the theories and practices connected with their construction, it may perhaps prove of some value to some one if I give a condensed historical review of the evolution of earth dams and also a brief description of the dams above alluded to.

There have been many failures of reservoir embankments in England and as the experience of that country is covered by many generations, where ours extends only a few years into the past, let us take a glance first at English practice.

It may be said I think with truth, that very few embankments of proper slopes have ever given way under the pressure of water. They have generally failed : First, from insufficient waste way and, second, from the method of drawing out the water through pipes, culverts or tunnels.

The question of the proper design of spill ways does not enter into our inquiry as this subject has been fully treated elsewhere and the conditions for proper design are well understood by all hydraulic and water works engineers.

I will only say in passing that many failures of banks have been ascribed to defective outlets which have really been due to water overtopping the dam.

Assuming then that a dam has abundant length of overflow it is safe to say that the weak point is in the outlet.

In the embankments first built in England the pipes were laid through the artificial banks and the valves placed on the outside. Many failures occurred from the settling and fracture of the pipes under the weight of the embankments, and as there was no control to the water from the inside of course nothing could save the dam. This led to building culverts excavated in the hard ground under the embankments. In these culverts pipes were placed, with stop or cut off walls near the inner slopes. The valves were generally placed on the inside, either directly in line with the slope, or oftener in valve towers, of cast iron or masonry, connected with the tops of the dams by bridges.

The culverts have given way in most instances by settling under the weight of the embankment also by crossing the puddle trench or core of the dam without special precautions; and by having puddle placed around them. Puddle is a dangerous material to use where the heads are great. It is of course comparatively safe in the heart of an embankment but when placed around pipes or in a position where it can escape gradually under a small leak, it is to be used only with the greatest care.

The puddle trenches in most English dams are carried to great depths. Where the culverts were built across them the clay was very apt to settle and break the masonry. This led to constructing slip joints, which were clumsy contrivances and seldom successful, Afterwards it was found best to begin at the bottom of the puddle trench with masonry foundation and carry it up for the culvert to rest on. All these precautions however did not ensure success. In the first place the sinking of the trench for the core wall and the pumping of the fine materials out of the soil on each side of the centre line of the dam, is apt to disturb the ground and leave a poor foundation for the culvert. Several of the most eminent engineers in England have argued that the only safe way to take a pipe out from a reservoir is to drift a tunnel through the natural ground around the ends of the embankment, connected with a valve tower in the reservoir. The water can be taken either directly

into the tunnel or led out in pipes. Mr. A. R. Binnie, in a discussion before the Institute of Civil Engineers says: "By a tunnel outlet, he meant an outlet driven in the solid rock or shale, below the surface by mining either round the ends of the reservoir as in the case of the Stubden reservoir or passing deep into the solid rock or shale and below the bottom of the puddle trench as at Leeming and Leeshaw. By a culvert outlet he meant any brick or masonry work which was built under the embankment or in cutting which was afterward filled in and covered by the embankment." This engineer cites the failure of the Leeming reservoir as a case where the culvert was fractured at the puddle trench, although a slip joint had been used. The Leeshaw culvert with no slip joint was fractured under only 10 feet of embankment. The failure of the Vartry reservoir, in Dublin, in June, 1867, was due to water finding its way between the rock and the puddle which surrounded the outlet culvert.

Mr. Bateman, who had built more than a hundred reservoirs, great and small, said in the same discussion,* "But as to the proper mode of discharging water from reservoirs I am as uncertain as I was forty years ago. I have long ago abandoned puddle; in difficult circumstances I have no confidence in clay."

A. Jervis, another English engineer, contributing to the same discussion, thought the building of tunnels might be carried too far. The stratification might not be favorable for a tunnel. He suggested that a culvert built in an open trench along the side of the valley might be best, especially where the intersection with the puddle trench was in rock.

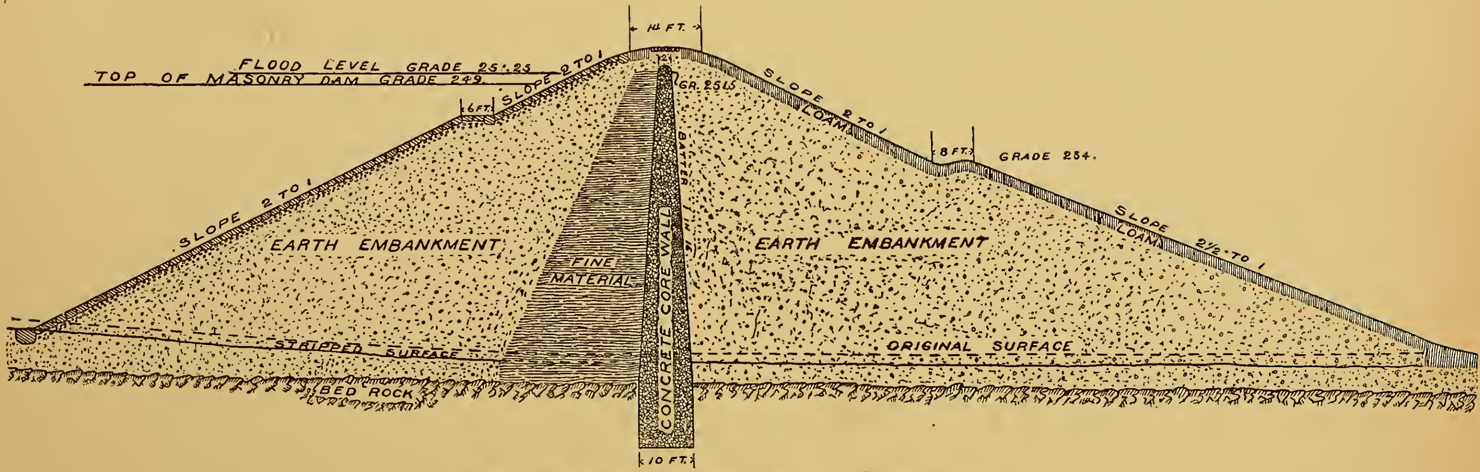
R. Hassard preferred where the ground was good, a culvert in deep trench on side of valley entirely under the puddle trench.

The failure of the Dale Dyke reservoir connected with the Sheffield Water Works is frequently alluded to in English publications. This embankment was 102 feet in height and it held 96 feet of water. It was poorly built and the pipes were carried through in a trench in the rock and surrounded with puddle. The valves were on the outside. Opinions differ as to the cause of the breach in the dam which resulted in the loss of 250 lives.

The almost universal practice in England is to build the inside slopes 3 to 1 and the outside slopes 2 to 1 and from observations of my own, particularly on Dam No. 4 of the Boston Water Works, I am inclined to believe that for high and important dams this is a good rule. It is almost needless to add that all pipes or culverts should be well provided with flanges and rings of masonry to prevent the water from creeping along the horizontal lines.

Allusion is frequently made to the old bunds in India and a word or two about these old dams may not be out of place. One of these forming the Cummins tank, consisted of an earth bank 102 feet high with 90 feet of water. The slope on the water side is 3 to 1 and on the outside ½ to 1 at top and 1 to 1 on the bottom, revetted, These old dams, which have stood for centuries, were made by dumping small amounts of earth from baskets and

*Vol. LIX. M. Inst. C. E.



SECTION OF RESERVOIR EMBANKMENT, BOSTON WATER WORKS.

they were consolidated in some cases by elephants treading upon the earth. No core wall was used. It has been stated that India is full of irrigation reservoirs which have failed by water following the outlet sluices.

According to Humbert the width of an earth dam on top cannot well be less than 6 to 8 feet and it is frequently 12 to 20 feet.

I believe Mr. Rawlinson's rule was 30 feet wide at the flood water level and this gentleman's rule for puddle cores was that the thickness should nowhere be less than one-third the head of water.

Having given a summary of English practice, I will now state the practice on the Boston Water Works and some reasons therefor.

The plate accompanying this discussion shows a section of an embankment about 65 feet in height. The slopes are 2 to 1 on the inside a berme 6 feet wide about 8 feet below the flood level. These slopes are paved on a broken stone foundation. The slopes on the outside are 2 to 1 down to the berme, which is 20 feet below the top, and 2½ to 1 below the berme. These slopes are covered with at least 2 feet of loam. The site is stripped of all soil containing organic matter, and after the core wall has been started the bank is built up in 4″ layers, watered slightly and rolled. The core wall is of concrete, plastered with Portland cement on the water side and with an occasional buttress on that side to stop the creeping of water lengthwise of the dam.

The core wall is carried to the rock 40 feet in places in the case of Dam No. 6, and is to be in a comparately shallow trench in the case of Dam 5, where the rock comes nearly to the surface.

Adjoining the core wall on the up stream side is placed selected fine and clayey material. The rest of the embankment is of gravel or whatever material may be convenient. The slopes however, both inside and outside should be of loose gravel to prevent the slipping on the water side when the reservoir is rapidly drawn down and to allow any leakage to pass freely away on the lower slope. This is an important point too often neglected.* Where the material on the slope is of a clayey nature, a slide is apt to take place, sometimes taking the paving or rip-rap down with it to the bottom of the reservoir.

In considering the stability of this kind of an embankment, we must assume that the full head of the reservoir is carried to the core wall which is intended to be water tight. The material on the down stream side of the wall must then, by its weight, withstand the pressure of the water, besides a saturated prism of earth on the upper half. The factor of safety is about two, in the case before us, so that it would not have been wise to make the slopes any steeper on the down stream side.

There are several ways of solving the problem of building a high dam of earth work. If there is to be no core wall, then perhaps it will be safer to make a gigantic filter of the section, as has already been done in the case of some of the canal banks in India. The inner slope is made as tight as possible, next fine sand is placed, giving way to coarser and coarser material, until the outer slope is met, which is composed of a mass of rubble stone. The object of this arrangement is to provide for the safe passage of any leakage

from the inside to the outside of the embankment without carrying with it any of the material of which the bank may be composed. In the case of an important dam holding back a large amount of water, which might cause great damage if suddenly released, it has always seemed to me that no chances should be taken. If the puddle is placed on the inner slope it will take more of it to accomplish the same result than if placed in the centre of the dam on account of the longer line which it follows. Again, a large sheet of puddle is more exposed to changes of condition and it is more liable to crack and leak and certainly it is more liable to change its position by slipping.

One of the advantages of a masonry core wall is that no animal can burrow through it, and it is more difficult for any small leak to grow larger than it is in the case of clay puddle. In the section given in the accompanying plate it will be noticed that curved surfaces have been given to many of the exterior angles of the section. They are more natural and easier to maintain than sharp corners, The berme, half way down the exterior slope, is introduced for drainage purposes, while the sod is forming. A gutter is formed in the berme, with slight slopes lengthwise of the dam leading to sod gutters running down the bank to keep the loam from being washed away by heavy storms.

In the case of Dam 6, the lower outlet pipe, 48" in diameter is laid in masonry on a rock foundation on the side of the valley. The core wall is carried over and around the masonry and besides these precautions, frequent cut off walls have been introduced along the line of the pipe. Another outlet pipe at a higher elevation is placed in a tunnel on a rock foundation at the other side of the valley. This pipe is placed in a tunnel because it is to be under pressure.

The valve towers or pits are of masonry and located just inside of the core wall which is continuous behind them.

In my own experience I have seen reservoir embankments fail which have never been alluded to in the public prints. It has occurred to me that some one anxious for a subject, for a thesis could not do better than to hunt up and describe accurately the conditions attending the failure of so many of our reservoir embankments, especially the details connected with the smaller reservoirs which have given way and which have never attracted public attention because they have been unaccompanied by loss of life or other serious damage.

I cannot agree with Mr. Taylor's statement that the tightest dams are those of earth. The tightest dams that I know of under great pressure have been carefully built stone dams.

In regard to what Mr. Tidd has stated about the dryness or wetness of materials I wish to say that it must be evident to all that there must be no lumps in the puddle or else it has not been thoroughly worked, but there is hardly any material which will absorb larger percentages of water than clay. If there is any chance for this water to drain off afterwards, immense cracks will result. The most satisfactory, solid and water tight puddle that we have used at Dam 6, has been that which contained the least water, but it must be

made perfectly homogeneous and thoroughly worked. In making a solid bank which shall be free from settlement, more depends upon the rolling and ramming than upon the watering.

We have built high embankments on the Boston Water Works which have not settled more than half an inch in fifty feet.

In building reservoir embankments an engineer must be guided by the local conditions and the resources at command, His design must be largely affected by the nature of his materials. There are certain general principles, however, which must be observed and which will be applied by an engineer of skill, judgment and experience to whatever design he may adopt. It is in the application of these principles that the services of the professional man become valuable, and it is from lack of them that there have been so many failures in the structures we have been describing

THE BURSTING OF THE PORTLAND RESERVOIR.

BY

JOHN R. FREEMAN, C. E.

(The President requested Mr. Freeman to describe the breaking of the Portland Reservoir.)

Mr. President, I will attempt to describe the accident very briefly. On Sunday morning the 6th of August, 1893, about 5.30 o'clock, the distributing reservoir of 20,000,000 gallons capacity on Munjoy Hill in Portland, Maine, gave away. It gave away without any previous warning. The Superintendent of the Water Works had visited the site within a very few days, and had been entirely around the embankment. Other men had also visited it within a comparatively short space of time, and there never had been a sign of the slightest degree of percolation anywhere, no rank growth of water grass, no damp spot or "spring" near the foot of the slope, although one part of the bank was 40 feet in height.

A man, whose house was demolished by the flood, testified that at 8 o'clock the previous evening he stood for some time leaning against the fence, scarce ten paces from where the break occurred, and his son who got home an hour after midnight noticed nothing wrong when he passed the spot.

The bank was built without a core wall, built of a material which, I should judge, was very much as Mr. Taylor has described as being used on the Lynde Brook reservoir.

The portion in the section indicated by the words "puddled bank" was from the natural clayey, gravelly, hardpan found on the spot, which was cut up, pulverized and compacted in 6-inch layers – well moistened and heavily rolled. Next the inside slope is shown, a puddle lining 4 feet thick which was an additional precaution to secure the greatest possible freedom from percolation—and consisted of an artificial mixture of about three parts of the natural crushed hardpan with one part of good blue clay, brought at considerable expense from across the back bay in the town of Deering. These were spread out in thin layers on a broad bed, mixed together thoroughly by Disc harrows, and then deposited in 6-inch layers and sprinkled, rolled and compacted like the rest.

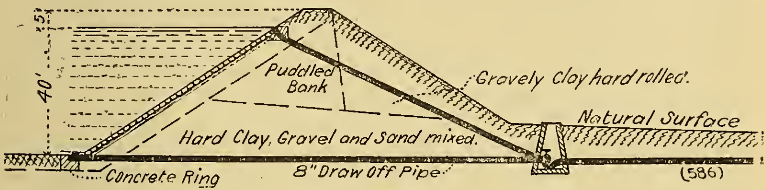
The portion marked "gravelly clay hard rolled" had no very distinct dividing line from the portion marked "puddled bank," but merely was the most pervious material and contained the natural loose earth on top of the hardpan mixed with a few chance cobbles of 2 to 4 inches diameter.

The natural substratum hardpan on which the embankment rested was as fine a natural hardpan as I ever saw. It was so very strong and tenacious that while the whole volume of that water was being poured out in a torrent over it, the hardpan proper was not cut into or washed away at any point to a depth of 6 inches. There was a trench cut down about 9 feet into the hard-

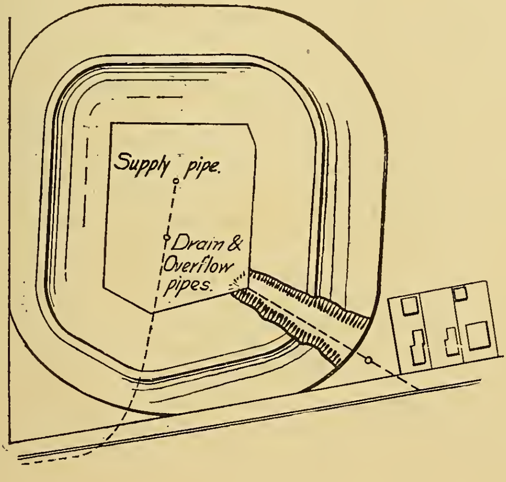
pan for laying the drain-pipe out from the reservoir, and after the washout the sides of that trench and the corners at the top of the bank showed almost as sharp and as clearly defined as on the day that trench was dug, while the first-class puddling material that had been compacted into that ditch was scoured out to a depth of perhaps 6 feet.

The break occurred at a point where the waste pipe, or the overflow-pipe, was laid out through the earth embankment. And in my judgment the break was due to the presence of this pipe.

Perhaps I had better first speak of how the break occurred, and what the



SECTION.



PLAN.

eye-witnesses say. At about 5 o'clock in the morning a woman, Mrs. Ellen M. Jones, who was visiting at a house very near the reservoir, was taking an early morning walk, accompanied by a little girl.

The little girl noticed a small stream spurting out of the ground at a point which appears to have been very nearly over the lower end of this waste-pipe, and said, "Look ! I have found a new spring." The elderly woman knew this stream meant something serious and with rare good sense ran to warn the

people who lived in two houses immediately down-stream. To her it is due that eight lives were saved. Had her warning been properly heeded no life need have been lost.

The progress of the break was very rapid. Probably when Mrs. Jones saw it first the hole was smaller than a man's wrist. Three minutes later, after she had aroused the people in danger, she found a "good large brook" coming through their door yard. Not more than fifteen minutes later the break had increased to a gap 40 feet across the top, two houses had been completely demolished—four people had been drowned—and the reservoir two-thirds emptied. The progressive character of the break was very interesting as described by the different eye-witnesses. The second person to see it called it big as a fire hose stream and thinks it issued from a place directly over the waste-pipe and 2 or 3 feet up from bottom of slope.

The next man described the water as spurting out of a hole "about as big as a man's leg;" a few minutes later there was another man got there, and his testimony at the inquest was that the hole was more than a foot in diameter and rapidly enlarging. And still another man who got there perhaps ten minutes after the first discovery, described the hole as being as large as a hogshead, and after that it increased very rapidly gullying out below, then caving down from above, forming a rude dam which soon cut out until finally a larger breakdown formed a barrier which held back the bottom 8 or 10 feet of the water in the reservoir and did not wash away.

The bank, so far as one can judge, from the testimony of those who built it, and from a careful examination of the ruins, was as thoroughly compacted and as well built as any one could ask for. From my careful examination of the ruins, I say without hesitation, a remarkably well built earth bank.

One thing which shows that the bank was put down in a good manner is that as this washout progressed the earth remained arched over the gap, until the gap had attained a width of perhaps 15 feet; that is, there was a hole at the bottom through which the water poured, and over which the upper part was continually crumbling in. The earth was so well compacted that it formed a natural arch over the hole, until the hole had got out to a width of perhaps 15 feet; and this arching certainly shows a good quality of earth-work.

Well, now, as to the cause of the break. As I have already said, there was a waste-pipe laid on a slope down through the bank, starting very near the high water line, and thence passing outward and downward on a straight slope through the bank. The overflow itself was formed in a block of concrete about 6 feet cube, and starting from that, an ordinary 12-inch bell and spigot cast iron tar-coated pipe was laid on a slope down through the bank.

There were no cut-off walls along this pipe. The pipe was laid by first building the embankment up all along, to a height of say 6 feet, just as though no pipe was there, rolling the 6-inch layers thoroughly meanwhile. Then, when all was ready to put in a pipe a sort of wedge shaped ditch was dug, which, at its lower end, was perhaps 6 or 7 feet deep with bottom sloping back up toward the inside at an angle of about 20 or 30 degrees and long enough to permit the putting in of one 12-foot length of water pipe.

After the lead joint was made in the ordinary manner, after plugging the upper end of the pipe to keep the dirt out, the men would puddle in around it very throughly with a mixture of nearly pure clay or of their best puddling material. After the ditch was thus filled up level they would treat the embankment as though there were no pipe there till they got up 6 or 7 feet more, and then dig out and insert another length of the cast-iron waste-pipe in the same manner as before.

After considerable investigation I came to the conclusion that there was no doubt that the break originated in connection with this waste-pipe through the embankment.

If there had been no waste-pipe there, I think there would have been no break.

Two or three things may have helped start the break.

First, this block of concrete at the head of the pipe had a nearly vertical face.

During the winter the ice, of course, was continually thrust against that block, and thrusting with almost irresistible force at times. As the water is frequently lowered a little and then rises again repeating this action again and again at different hours of the day as the influx and outflow vary, a sort of toggle-joint action of the ice against any vertical face of masonry may easily be produced.

Moreover, during the winter previous there was some very cold weather while the reservoir was drawn down nearly to its lowest level, and the embankment was exposed to very severe frost about Christmas time. You probably all have had experience with the effect of frost on a moist clay bank the inside lining of this reservoir was practically a moist clay bank. That moist clay bank would heave under the influence of the frost, and that would also lift with great force against the 36 square feet of area on the level bottom of this concrete block.

Since this block was firmly built on to the pipe, the pressure against this block, prying away at the end of the pipe, would have something the same effect as when you have a crow-bar run into a bank of earth and pry away at the end of the bar; you will loosen the earth immediately around the bar where it enters the bank.

Here I think it likely that some similar action occurred in loosening the earth a very little, from its close contact with the upper end of the pipe, perhaps the crack was not thicker than a sheet of paper around the upper part of the pipe.

Then there is another thing which I think may have had some influence. The puddling material around this pipe was put in rather more moist than the material in the rest of the bank.

If there was an excess of water used there, there naturally would be a slight tendency to shrinkage after that excess of water got more evenly distributed through the rest of the embankment, and as that shrank there would be a tendency for the earth to grip the pipe a little less securely than it did at first.

Very many of you have had forced on your attention the great tendency of water to follow along a smooth iron pipe. This is found on pipes sloping down a hill in wet ground and I have often seen it follow along iron water wheel penstocks.

I think it was a fatal oversight not having cut-off walls along the pipe.

I will take time only to suggest one other point, on which some of the other members may bring valuable information to bear, and which has just been suggested in what I said about this puddled trench around the pipe having been put in a little more moist than the rest of the embankment.

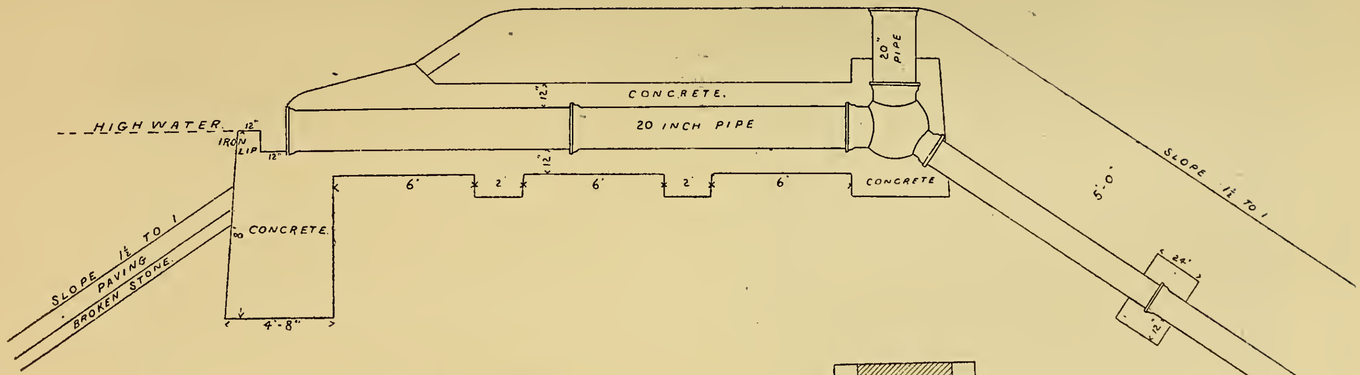
The question is whether one can make a tight embankment better by putting the material down wet or putting it down dry. Some experiments that our fellow member, Mr. FitzGerald made at Chestnut Hill some years ago, are very instructive as to what happens if earth is compacted in a moist condition. He desired to fill a box, (which, as I remember it, was some 6 feet cube) with earth as compactly as possible. He found that when he puddled the earth into the box and then left it exposed to the atmosphere, there was a shrinkage of the earth, that it shrank away from the sides of the box nearly a quarter of an inch when it became thoroughly dry; and he found he could get a greater amount of earth into this box—could get it in so it would hug the sides more closely, by ramming it in a dry condition than he could by putting in water and puddling it and pounding it down. This is quite a fruitful topic for discussion, and so with its suggestion I will close.

DISCUSSION.

Mr. Fuller. I would like to ask with regard to this Portland reservoir, whether the waste pipe could not have been carried out in the same trench in which the inlet pipe was laid? And, also, whether it would not have been better if the waste pipe had been carried out from the gate-chamber, in which case there would have been no trouble from the ice.

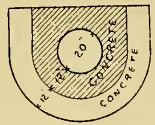
Mr. Freeman. There was no gate chamber there. The inlet pipe came in on one side of the reservoir and rested down on the natural hardpan. The outlet pipe went out at the other side, and that also rested on the hardpan. Those were on the up-hill side of the reservoir, however, and the natural place for pipes for taking off the overflow and for draining the reservoir to the very bottom was on the other side of the reservoir where the ground was lower.

Mr. Tidd. I consider that a pipe like that mentioned in the case of the Portland reservoir, is a very dangerous thing to put in. I may have done many risky things, but I don't think I ever did that. I think Mr. Freeman has given the practical solution of the difficulty in Portland. There can be no doubt in the mind of any engineer but that the pipe must have been lifted by the frost, as he says; for the ice pushed fearfully hard, and sometimes it falls below, as he says, it drops into a V, and when it returns again it opens the other way and causes a great pressure. And there is no doubt in my mind that it moved the pipe enough to leave a chance for the water to start down through there.



OVERFLOW PIPE AS REBUILT

SCALE 8 FEET TO AN INCH



SECTION ON LINE A

Mr. Brackett. In continuation of the description Mr. Freeman has given us of the Portland reservoir, it may perhaps interest you to know how the break was repaired, and what means have been taken to prevent a recurrence of the same accident. In repairing the break, the material on the sloping sides of the break was very carefully removed to a sufficient distance to be sure that no incipient cracks might be remaining, and then it was very carefully replaced in thin layers. Perhaps I ought rather to say that this is the method which was recommended by the engineers who examined the break for the Company ; this is their recommendation, which I understand has been carried out. But, as Mr. Freeman has stated, the cause of the break was supposed to be the waste-pipe, which, in the original construction, started from a quarter turn set in a concrete block and went down through the center of the bank. In repairing, a block of concrete 8 feet in depth was put in deep enough to go below the reach of the frost, and a 20-inch pipe carried horizontally, or with a very slight pitch, across near the top of the embankment, surrounded on all sides by concrete with cut-off walls ; and near the outer side of the embankment a pipe is carried up, permitting access to the horizontal 20-inch pipe so that it can be examined at any time and any signs of movement detected. From this point near the outer side of the embankment, a 12-inch pipe is carried down the outer slope about 4 feet below the surface. The embankment has been widened at this point, which was a corner of the reservoir, so that the new drain is entirely outside the lines of the old embankment.

A CHEAP COVERED RESERVOIR,

BY

JOHN C. CHASE, Superintendent, Wilmington, N. C.

[Read Jan. 10th, 1894.]

The remarks made by Mr. Noyes at the last meeting of the Association relative to the variation in the dimensions of details as affecting the cost of engineering works designed for the same general purpose and where supposably the same general conditions existed, variations caused perhaps by the different ideas of the engineers in charge, or perhaps on account of the limitations of the location, suggested that a description of a cheap covered reservoir with detailed cost of construction might be of interest.

The city of Albany, Ga., derives its water supply from artesian wells, but the hourly flow not being equal to a possible maximum hourly draught, it became necessary to provide for a storage of about 250,000 gallons. The city lot on which the pumping station and water tower were to be erected had a frontage of only 105 feet, with a depth of 210 feet, and with this limited area it was decided to build a circular basin 60 feet in diameter with a depth at the side wall of 13 feet, the bottom having a uniform slope of one foot to the center. On account of the expense of disposing of the material excavated, the structure was built only about one-half in excavation. The excavation was in a very compact red clay, so hard in fact that the city in building cisterns 15 feet deep and 18 feet in diameter for fire-engine supply, have merely plastered the vertical side of ths excavation with hydraulic cement mortar, using a brick dome of about five feet rise for covering.

In this hard material it was practicable to build a very light lining wall of 16 inches in thickness, which rested on a slight footing course about 8 inches below the bottom of the reservoir. The excavation was cut out very carefully about one-half inch larger than the exterior of the wall. In laying the brick, Portland cement was used for the inside course, and Rosendale for the other three courses, and the half-inch space outside of the brick-work was flushed full of cement, so that practically it is earthen well lined with brick. The wall was carried about 6 feet above the natural surface of the ground and received a coating of cement mortar on the outside. The excavated material was filled back against the wall, being deposited in layers, dampened and thoroughly rammed. The filling was carried to a point one foot below the top of the wall and finished with a berme of four feet and a slope of one and one-half to one. The lining of the bottom was a course of brick set on edge in a bed, and with a joint of Portland cement mortar. It was intended to cover the interior surface with a coating of Portland cement grout applied with a brush, but through some misunderstanding it was plastered with Portland cement mortar $\frac{1}{4}$ inch thick. The character of the water was such that it was necessary to exclude

the sunlight, and a wooden roof seemed to be the cheapest and most feasible device. A brick pier 20 inches square was built in the center of the reservoir which carried one end of twelve principal radial trusses with 8 feet rise, made of $1\frac{1}{2}$ inch by 10-inch yellow pine plank. The chords and rafters were made up of two thicknesses of plank, separated by the diagonal members, the whole being securely fastened by bolts and spikes. The covering was of $\frac{3}{4}$-inch weather boarding 9 inches wide and laid 6 inches to the weather. The butt joints at the ridges over the trusses were covered with a flashing of tin as each course of the weather boarding was put on and on completion the roof received two coats of mineral paint. It is designed to cover the roof with metal when the present covering begins to show signs of decay. The roof is surmounted by a hexagonal cupola, with suitable openings to it, and also at the eaves, for ventilation, which are protected by galvanized wire screens. The roof water falls from the eaves into a shallow paved gutter and is carried down the bank by three lines of 6 inch drain pipe, in order to preserve the slope. The supply from the wells is carried over the top of the wall and a suitable overflow pipe provided. Also a drain pipe, which starting from the center will permit of entirely emptying the reservoir. The pump supply is drawn from near the bottom and on the opposite side to the inflow pipe. The reservoir has been in use some fifteen months and is believed to be thoroughly water tight. It has been filled and emptied several times, and has shown no signs of bulging or distortion. and with the precautions taken to prevent surface water from finding its way down behind the wall, and to keep the contents from leaking out, it is hard to conceive of any hydrostatic pressure ensuing, tending to rupture the sides or bottom. The detailed cost is as follows :

101,500 Brick, at $4.75	$482.63
78 Bbls. Portland Cement at $2.90	226.20
51 " Rosendale " " 1.65	84.15
103 Loads of Sand " .50	51.50
Labor of Excavating and Bricklaying	611.88
Incidentals	12.00
Contract for Roof, complete	309.00
Total,	$1,777.36

The work was all done by the day excepting the roof, which was contracted for. The prices paid were, for unskilled labor $0.75 ; masons, $3.00 ; foreman, $4.00 and the days work averaged about eleven hours. This fact and the low price of brick will account in part for the low cost of construction. Snowfalls being very light and infrequent, permitted a much lighter roof construction than would be possible in less favored localities. The full capacity of the reservoir is about 280,000 gallons.

A METHOD OF RECORDING THE LOCATION OF WATER MAINS AND SERVICES.

BY

Geo. A. Kimball, Civil Englneer, Boston, Mass.

(Read Jan. 10th, 1894.)

This method was adopted for recording the location of water mains and services in the city of Somerville about fifteen years ago and is still in use. Ordinary field note books are used, each book containing a certain district of the city. The pages of the book are divided into $\frac{1}{4}$ inch squares for the purpose of laying off the distances substantially to a scale. The street is drawn down the middle of the page and continued on the next pages until it is finished. The arrows indicate corresponding points on the pages. On each side of the street are drawn the houses, fences and other structures. In the streets are shown the mains, water services, gates, hydrants, all of which are laid off to a scale by using the squares. Measurements are taken to the pipe from the buildings and other permanent structures. Main pipes are laid one-third the width of the streets from the side line.

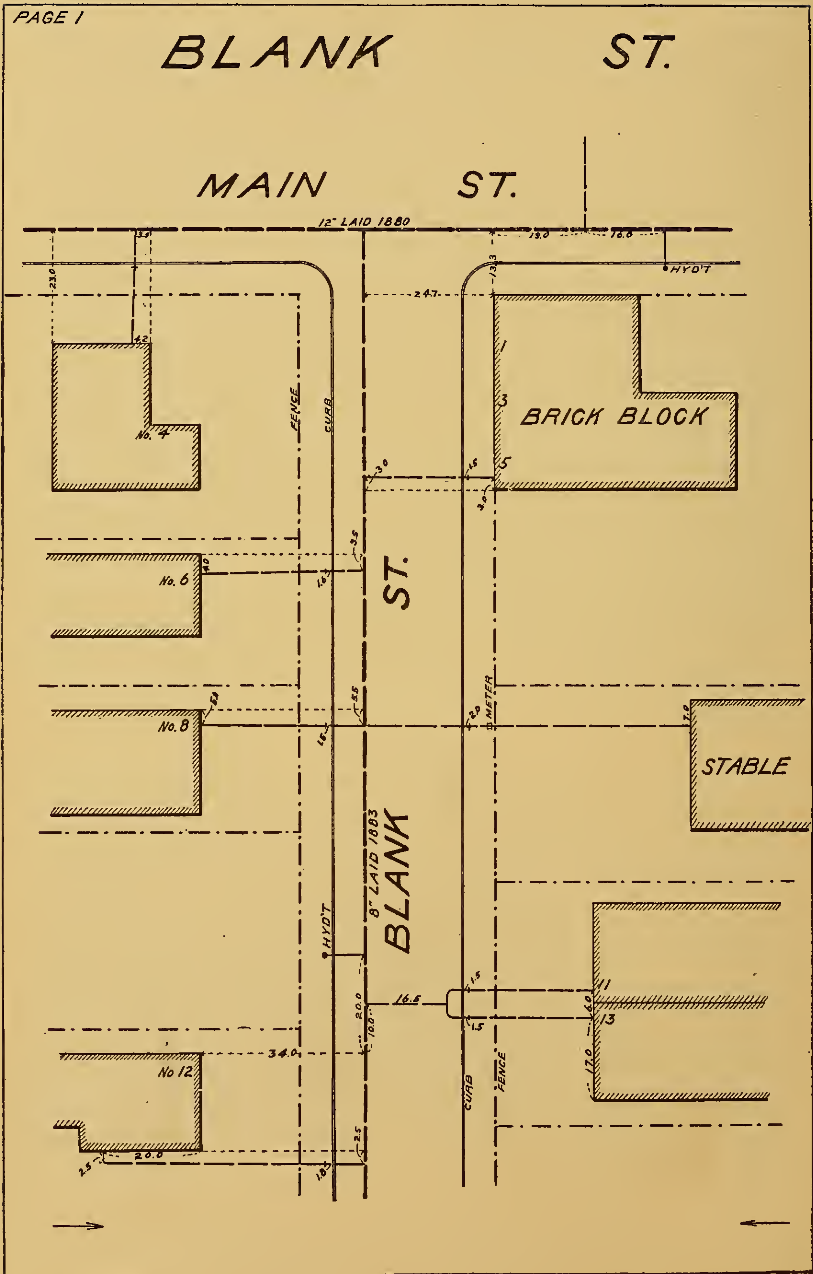
The advantages are that the books contain a complete record of all water pipes and connections. They can be referred to quickly as the streets are arranged in alphabetical order. The books can be carried in the pocket and used on the ground if desired. The following page is a sample page in the note book.

DISCUSSION.

Mr. Fuller. I would say that I have followed a system somewhat similar to this, except that I have made it a practice to keep the service pipe locations in a separate book. In locating and showing the main pipes, my practice has been to make sketches on tracing cloth, showing the pipes with the gates, and then make enlarged sketches to show the location of the gates more clearly. I would have the distances, from the houses, perhaps every 50 or 100 feet, so that the pipe could be located in case the location of the pipe was wanted when sewers were put in, or anything of that kind. I have made these sketches on tracing cloth, perhaps a sheet 3 feet square, divided off, so that after taking blue prints from this tracing I could bind these blue prints into book form, and still preserve the original sheets on tracing cloth with the locations upon them. The advantage of this is that if the book is lost you still have the originals, and all you have to do is to take the blue prints, copy off the sheets and bind them in a book, so that the original book is not carried into the street at all.

LOCATION OF WATER MAINS AND SERVICES

SAMPLE FROM PAGE OF NOTE BOOK



Mr. Harrington. In Cambridge, and I suppose it is the same in most cities, the information that is wanted on the street, is the location of the gates and pipes. We have a book, which is perhaps one-third the size of the one Mr. Kimball has shown, which shows the location of the gates and the pipes, and the measurement to them. The two locations are mainly at right angles from the line of the street. In that way we get all the information we want on the street. The other information with regard to the supplies and the other things which Mr. Kimball may have in his book, is wanted quite frequently and more generally in the office, and that we have on a separate book, dividing the city into districts. It seems to me the measurements ought to be taken from the fence line, or the line of the street, for we find in Cambridge the houses are moved frequently, thus throwing the measurements out entirely.

Mr. Brackett. It is a good plan to locate pipes and gates in such a manner that they can be easily found without reference to records or plans. With this end in view, pipe should be laid at regular distances from the lines of the streets and gates located opposite the lines of cross streets. Every branch from pipes twelve inches in diameter and larger should have a gate at the connection. These rules cannot be followed in all cases, but when adopted as far as possible they will greatly simplify the system.

Record plans showing all pipes, gates and hydrants on a scale as large as 100 feet to an inch should be made and frequently corrected to show all additions or changes in the system.

In Boston, detail drawings of all important or complicated connections, giving locations of gates. are made on sheets $3\frac{1}{2} \times 6$ in and bound in pocket book form for ready reference.

The point which it seems to me should be impressed upon all superintendents and engineers in charge of water works, is the necessity of always keeping a careful record of all work done, in such a manner that it can be conveniently referred to at any time. The tendency in many cases has been to keep all of the records in the brain of the superintendent, a very unsafe practice.

OBITUARY.

ROBERT K. MARTIN—Chief Engineer Water Works, Baltimore Md. Died November 24th, 1893, aged 58 years. Joined this Association, June 13th, 1889.

Mr. Martin was Chief Engineer and designer of the Druid Hill Reservoir, the High Service Reservoir in 1871 and the Gunpowder River Supply Works, including the big tunnel commenced in 1875. He was connected with the Baltimore Water Department for over 37 years and was its executive official for nearly 30 years. He took a high rank as a consulting engineer and was offered the position as consulting engineer by the New York authorities in the matter of construction of water works.

EUGENE P. LEBARON—Chairman Water Board, Middleboro, Mass. Died December 1st, 1893. Joined this Association, February 12th, 1890.

Mr. LeBaron acceptably filled many positions of trust and confidence as well as the one above mentioned, and enjoyed the respect and confidence of his fellow citizens to a marked degree.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VIII. June, 1894. No. 4.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

ADJOURNED MEETING.

YOUNG'S HOTEL, BOSTON, Feb. 16th, 1891.

The following members and guests were present:

MEMBERS.

Everett L. Abbott, Civil Engineer, New York City; Richard W. Bagnell, Supt., Plymouth, Mass.; Charles H. Baldwin, Boston, Mass.; Lewis M. Bancroft, Supt., Reading, Mass.; George E. Batchelder, Registrar, Worcester, Mass.; Joseph E. Beals, Supt., Middleboro, Mass.; Dexter Brackett, Assistant Engineer, City Engineer's Office, Boston, Mass.; A. W. F. Brown, Registrar, Fitchburg, Mass.; John M. Burleigh, Supt, South Berwick, Me.; George F. Chace, Supt, Taunton, Mass.; William F. Codd, Supt., Nantucket, Mass.; Freeman C. Coffin, Civil Engineer, Boston, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass.; Byron I. Cook, Supt, Woonsocket, R. I.; George E. Evans, Civil Engineer, Boston, Mass.; Elmer E. Farnham, Supt., Sharon, Mass.; B. R. Felton, City Engineer, Marlboro, Mass.; Desmond FitzGerald, Supt. Western Division, Boston, Mass.; William E. Foss, Assistant Engineer Boston W. W., Brighton, Mass.; Frank L. Fuller, Civil Engineer, Boston, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; J. A. Gould, Jr., Engineer Brookline Gas Light Co., Boston, Mass.; E. H. Gowing, Civil Engineer, Boston, Mass.; Frank E. Hall, Supt., Quincy, Mass.; John C. Haskell, Supt., Lynn, Mass.; Horace G. Holden, Supt. Nashua, N. H.; Horatio N. Hyde, Supt., Newtonville, Mass.; E. W. Kent, Civil Engineer, Woonsocket, R. I.; Willard Kent, Civil Engineer, Woonsocket, R. I.; George A. Kimball, Civil Engineer, Boston, Mass.; Horace Kingman, Supt., Brockton, Mass.; Wilbur F. Learned, Assistant Engineer Boston W. W., Watertown, Mass.; William McNally, Registrar, Marlboro, Mass.; Albert F. Noyes,

Assistant Chief Engineer State Board of Health, Boston, Mass.; Joseph K. Nye, Fairhaven, Mass.; Edward H. Phipps, Supt., New Haven, Conn.; George S. Rice, Civil Engineer, Boston, Mass.; Walter H. Richards, New London, Conn.; J. W. Ringrose, Commissioner, New Britain, Conn.; W.W. Robertson, Registrar, Fall River, Mass.; Henry W. Rogers, Supt., Haverhill, Mass.; Daniel Russell, Everett, Mass.; F. J. Shepard, Treasurer, Derry, N. H.; William H. Thomas, Supt., Hingham, Mass.; M. M. Tidd, Civil Engineer, Boston, Mass.; R. H. Tingley, Civil Engineer, Pawtucket, R. I.; D. N. Tower, Supt., Cohassett, Mass.; W. H. Vaughn, Supt., Wellesley Hills, Mass.; Charles K. Walker, Supt., Manchester, N. H.; Horace B. Winship, Civil Engineer, Norwich, Conn.; George E. Winslow, Supt., Waltham, Mass.; E. Worthington, Jr., Civil Engineer, Boston, Mass.; C. W. Houghton, Ashton Valve Co., Boston, Mass.; James M. Betton, Agent H. R. Worthington, Boston, Mass.; A. H. Broderick, Chadwick Lead Works, Boston, Mass.; M. H. Crawford, The Radford Pipe and Foundry Co., Boston, Mass.; F. H. Hayes, Dean Steam Pump Co., Boston, Mass.; Charles H. Eglee, Flushing, N. Y.; A. H. Davis, William H. Gallison, Boston, Mass.; Henry F. Jenks, Pawtucket, R. I.; S. B. Adams, Peet Valve Co., Boston, Mass.; H. L. Bond, Perrin, Seamans & Co., Boston, Mass.; H. H. Kinsey, Rensselaer Manufacturing Co., Troy, N. Y.; W. H. VanWinkle, Anthony P. Smith, Newark, N. J.; F. A. Snow, Providence, R. I.; I. W. Dodge, Standard Thermometer Co., Peabody, Mass.; J. P. K. Otis and G. H. Carr, Union Water Meter Co., Worcester, Mass.; B. F. Polsey and J. H. Eustis, Walworth Manufacturing Co., Boston, Mass.; H. A. Gorham, The George Woodman Co., Boston, Mass.; H. B. Temby, Boston, Mass.; H. D. Winton and J. A. Tilden, Hersey Manufacturing Co., South Boston, Mass.

GUESTS.

William S. Danforth, Plymouth, Mass.; John T. Desmond, Haverhill, Mass.; Frank L. Elkins, Boston, Mass.; George Goodhue, Concord, N. H.; James Gorman, Boston, Mass.; D. D. Jackson, Newtonville, Mass.; James W. Locke, Brockton, Mass.; John Moore, Lancaster, N. H.; J. J. Moore, Hingham, Mass.; Thomas Naylor, Maynard, Mass.; E. T. Spear, Quincy, Mass.; S. H. Taylor, New Bedford, Mass.; William F. Williams, New Bedford, Mass.; H. C. Tower, Cohassett, Mass.

The Secretary presented the applications of the following named for membership:

RESIDENT ACTIVE MEMBERSHIP.

George A. Devlin, Civil Engineer, Marlboro, Mass.
Charles R. Felton, Civil Engineer, Brockton, Mass.
David A. Hartwell, City Engineer, Fitchburg, Mass.
Perry Lawton, Civil Engineer, Quincy, Mass.
Warren B. Wheeler, Assistant City Engineer, Fitchburg, Mass.
William F. Williams, City Land Surveyor, New Bedford, Mass.
Thomas Naylor, Superintendent, Maynard, Mass.
Cornelius F. Doherty, Water Registrar, Boston, Mass.

NON-RESIDENT ACTIVE MEMBERSHIP.

D. A. Reed, City Engineer, Duluth, Minn.
Frederic V. Pitney, Civil Engineer, Morristown, N. J.
W. H. Burr, Prof. Civil Engineering, Columbia College, New York City.
J. Olivier Delisle, Civil Engineer, 443 Dorchester St., Montreal P., Q.

On motion of Mr. Tidd the Secretary was directed to cast the ballot of the Association for the candidates, and that having been done, they were declared elected.

The President called attention to the bill pending before the Massachusetts Legislature, entitled "An 'Act' for the appointment of a State Inspector of Water Meters," and the Secretary read for the information of the members the principal sections of the bill.

Mr. Brackett called attention to the circular to be sent out by Mr. Coffin and requested members to fill out the blanks as far as possible and return them to Mr. Coffin. He stated that the information obtained would be interesting and valuable and would be given to the Association.

Experience talks and papers were contributed by Mr. A. F. Noyes, Mr. Byron I. Cook, Mr. W. F. Codd and Mr. Joseph K. Nye, and the discussions were participated in by Mr. FitzGerald, Mr. Tidd, Mr. Coffin, Mr. Brackett, Mr. Holden, Mr. Ringrose, Mr. Fuller, Mr. Winslow, Mr. Haskell and others.

Mr. Holden asked if it was necessary to remove all loam as well as roots and stumps from newly flowed land in order to secure freedom from bad taste in the water.

Mr. Ringrose stated that in building a new reservoir at New Britain, the muck and roots had been removed but not the loam.

Mr. FitzGerald stated that from experiments made under his direction the conclusion was reached that in ordinary soils the larger part of the organic matter was in the first foot in depth.

[Adjourned.]

QUARTERLY MEETING.

Young's Hotel, Boston, March 14, 1894.

The following members and guests were present:

MEMBERS.

Everett L. Abbott, Civil Engineer, New York City; Charles H. Baldwin, Boston, Mass.; George E. Batchelder, Registrar, Worcester, Mass.; Joseph E. Beals, Superintendent, Middleboro, Mass.; Nathan B. Bickford, Supt. W. W. N. Y., N. H. & H. R. R., Old Colony Division, Boston, Mass.; William R. Billings, Taunton, Mass.; Arthur W. F. Brown, Registrar, Fitchburg, Mass.; John M. Burleigh, Supt., South Berwick, Me,; George F. Chace, Supt., Taunton, Mass.; E. J. Chadbourne, Supt., Wakefield, Mass.; Charles E. Chandler, City Engineer, Norwich, Conn.; John C. Chase, Supt., Wilmington,

N. C.; Freeman C. Coffin, Civil Engineer, Boston, Mass.; R. C. P. Coggeshall, Supt., New Bedford, Mass,; Byron I. Cook, Supt., Woonsocket, R. I.; F. H. Crandall, Supt. and Treasurer, Burlington, Vt.; George K. Crandall, Civil Engineer, New London, Conn.; L. E. Daboll, Supt. New London, Conn.; Edwin Darling, Supt., Pawtucket, R. I.; Prof. Thomas M. Drown, Mass. Inst. Tech., Boston, Mass.; Horace L. Eaton, City Engineer, Somerville, Mass.; Frank L. Fales, Lawrence, Mass.; Loring N. Farnham; Civil Engineer, Boston, Mass.; B. R. Felton, City Engineer, Marboro, Mass.; F. F. Forbes, Supt., Brookline, Mass.; Frank L. Fuller, Civil Engineer, Boston, Mass.; George W. Fuller, Biologist, Lawrence, Mass.; Albert S. Glover, Boston, Mass.; J. A. Gould, Jr., Engineer Brookline Gas Light Co., Boston, Mass.; E. A. W. Hammatt, Civil Engineer, Boston, Mass.; George W. Harrington, Wakefield, Mass.; David A. Hartwell, City Engineer, Fitchburg, Mass.; John C. Haskell, Supt., Lynn, Mass.; L. M. Hastings, City Engineer, Cambridge, Mass.; Louis Hawes, Civil Engineer, Boston, Mass.; Clemens Herschel, Hydraulic Engineer, New York City; James H. Higgins, Supt. Meter Dept. Providence, R. I.; Horace G. Holden, Supt., Nashua, N. H.; E. W. Kent, Civil Engineer, Woonsocket, R. I.; Willard Kent, Civil Engineer, Woonsocket, R. I.; Patrick Kieran, Supt., Fall River, Mass.; George A. Kimball, Civil Engineer, Boston, Mass.; Prof. Leonard P. Kinnicutt, Worcester, Mass.; Cyrus B. Martin, Treas., Norwich, N. Y.; Josiah S. Maxcy, Treas., Gardiner, Mass.; William E. McNally, Registrar, Marlboro, Mass.; Thomas Naylor, Supt., Maynard, Mass.; Albert F. Noyes, Assistant Chief Engineer State Board of Health, Boston, Mass.; Edward H. Phipps, Supt., New Haven, Conn.; Dwight Porter, Assoc. Prof. Hyd. Engr. Mass. Inst. Tech., Boston, Mass.; George J. Ries, Supt., Weymouth Centre, Mass.; J. W. Ringrose, Commissioner, New Britain, Conn.; W. W. Robertson, Registrar, Fall River, Mass.; Henry W. Rogers, Supt., Haverhill, Mass., A. H. Salisbury, Supt., Lawrence, Mass.; F. J. Shepard, Treas., Derry, N. H.; Prof. Herbert E. Smith, Yale Medical School, New Haven, Conn.; J. Waldo Smith, Civil Engineer, Montclair, N. J.; George A. Stacy, Supt., Marlborough, Mass.; William W. Starr, Jr., Civil Engineer, Bridgeport, Conn.; Frederic P. Stearns, Chief Engineer State Board of Health, Boston, Mass.; S. G. Stoddard, Jr., Engr. Hyd. Co., Bridgeport, Conn.; Prof. George F. Swain, Mass. Inst. Tech. Boston, Mass.; Charles H. Swan, Civil Engineer, Boston, Mass.; Lucian A. Taylor, Constructing Engineer, Boston, Mass.; William H. Thomas, Supt., Hingham, Mass.; M. M. Tidd, Hydraulic Engineer, Boston, Mass.; D. N. Tower, Supt., Cohassett, Mass.; W. H. Vaughn, Supt., Wellesley Hills, Mass.; Charles K. Walker, Supt., Manchester, N. H.; Warren B. Wheeler, Assistant City Engineer, Fitchburg, Mass.; William F. Williams, City Surveyor, New Bedford, Mass.; Horace B. Winship, Civil Engineer, Norwich, Conn.; George E. Winslow, Supt., Waltham, Mass.; S. J. Winslow, Supt., Pittsfield, N. H.; E. Worthington, Jr., Civil Engineer, Boston, Mass.; James M. Betton, Agent H. R. Worthington, Boston, Mass.; A. H. Broderick, Chadwick Lead Works, Boston, Mass.; F. H. Hayes, Deane Steam Pump Co., Boston, Mass.; Charles H. Eglee, Contractor, Flushing, N. Y.; George A. Taylor, Gilchrist & Taylor, Boston, Mass.; William d'H.

Washington, The Hydraulic Cons. Co., New York City; Henry F. Jenks, Drinking Fountains, Pawtucket, R. I.; S. B. Adams and F. E. Stevens, Peet Valve Co., Boston, Mass.; Harold L. Bond, Perrin, Seamans & Co., Boston, Mass.; W. H. VanWinkle, Anthony P. Smith, Newark, N. J.; H. B. Temby, Repauno Chemical Co., Boston, Mass.; S. D. Higley and E. T. Ivins; Thomson Meter Co., Brooklyn, N. Y.; W. H. Moulton, Union Water Meter Co., Worcester, Mass.

GUESTS.

Hon. Thomas A. Bancroft, Cambridge, Mass.; J. G. Barrin, Civil Engineer, Boston, Mass.; Harry W. Clark, Lawrence, Mass.; C. H. Darragh, Philadelphia, Penn.; George Goodhue, Concord, N. H.; E. Eugene Eglee, New York City; Harry Gould, Troy, N. Y.; T. G. Hazard, Jr., Narragansett Pier, R. I.; F. A. Houdlette, Boston, Mass.; H. J. Jernigan, Fall River, Mass.; James A. Jones, Stoneham, Mass.; Mr. Kieran, Fall River, Mass.; B. J. Reith, Peabody, Mass.; George I. Tarr, Rockport, Mass.; S. H. Taylor, New Bedford, Mass.

The Secretary presented the applications of the following names for membership :

RESIDENT ACTIVE.

J. L. Moore, Supt., Lancaster, N. H.; Daniel D. Jackson, Water Analyst, Boston Water Works, Newtonville, Mass.; Willard T. Sanborn, Supt. Dover, N. H.; Alexander Potter, Civil Engineer, 137 Broadway, New York; Arthur S. Tuttle, Assistant Engineer Water Works, Brooklyn, N. Y.; James A. Jones, Registrar, Stoneham, Mass.; Harry W. Clark, State Experimental Station, Purification of Sewage, Lawrence, Mass.

ASSOCIATE.

National Lead Company, New York City; E. Eugene Eglee, Construction Water Works, New York City.

On motion of Prof. Drown the Secretary was directed to cast the ballot of the Association in favor of the applicants, which he did and they were declared elected to membership.

The President announced that the associate members, although requested by the Secretary to do so, had failed to select anybody to take charge of the exhibits at the next annual convention, and suggested that the Association take some action.

On nomination of Mr. Stacy, Mr. Harold Bond (with Perrin, Seamans & Co.) was selected to represent the associate members at the June convention.

The Secretary read a communication from Mr. Richards the Junior Editor, calling attention to the recent ruling of the Post Office Department refusing admission to the mails of society proceedings at pound rates, and requesting

members to write their respective representatives in Congress in favor of inserting a provision in the Manderson-Hainer bill now pending to include the publications of scientific and educational societies.

He also read a circular issued by the Boston Society of Civil Engineers to their members, on the same subject.

The President then introduced his Honor W. A. Bancroft, Mayor of Cambridge, who made a brief address. The first paper of the afternoon was by Prof. Thomas N. Drown of the Massachusetts Institute of Technology, upon "Electric Purification of Water and Sewage." The subject was discussed by Mr. Stearns, Prof. Smith, Mr. Herschel, Mr. Darling and Mr. Chace.

L. M. Hastings, City Engineer of Cambridge, then read a paper describing some experiments in measuring the flow of water in a 36-inch pipe. Prof. Porter, Mr. Coffin and Prof. Swain spoke upon the same subject.

[Adjourned.]

ADDRESS OF HON. W. A. BANCROFT,

MAYOR OF CAMBRIDGE.

[March 14, 1894.]

THE PRESIDENT. I have the honor of introducing to you the Hon. William A. Bancroft, Mayor of Cambridge. (Applause.)

MR. BANCROFT. Mr. President and gentlemen of the Association: I count it a high honor to have the privilege of coming here and facing this solid phalanx of New England manhood, representing as it does the intelligence, the prosperity, and the progress of our country, (for our country does not get very much ahead of New England, and I for one hope that the country will keep up to New England, for this is a standard of which it may well be proud,) men gathered here fit to associate with the gentlemen whose faces look down upon you from these walls, whose cares and responsibilities, to be sure, have ended, but no one of whom I venture to say, no matter how eminent, knew as much about water supply as you do. (Laughter and applause.)

I am here vicariously for one of your honored members, a former president of this Association, a sturdy son of Maine, whom the city of Cambridge long ago inveigled into its service, and which owes him very much more than he owes it, your present Treasurer, Hiram Nevons. I don't know that you feel any anxiety about the condition of the funds you may have entrusted to his care. I wish the funds of this country were in as safe hands as yours are. (Laughter.) No political reference whatever! (Laughter.) But I am sorry that Mr. Nevons is not here. You know his worth, as we know his worth. I wish he were here to join with you. I know the pride he feels in this pioneer association of municipal officials, for such an association it is.

What an object lesson this Association of yours would be to pessimists who are constantly declaring that municipal government in our country is a failure, because of the character of its public service. (Laughter and applause.) But Nevons is not here, and the poor man, I am afraid, is sick. His rugged constitution, which he has impaired, I have no doubt, by his fidelity to the service in which he is engaged, has become somewhat enfeebled. We hope he will regain his wonted health and strength. Such strength as he has he daily devotes to going to our water system, where we are engaged and have been engaged during the winter in some work, showing his fidelity in that way rather than by taking his strength to come in here, which certainly, would be more pleasurable.

I bring, too, the greetings of another water official, I do not know, sir, whether he was a member of your Association or not, the Hon. Chester W. Kinsley who for twenty-nine years was a member of our Water Board, most of the time at its head, and who last winter retired from a service seldom paralleled in this country, in this community or any other, for efficiency, for he was at the forefront of all our Water Board fights, and has succeeded in solving very many of the difficult problems which we have had to encounter in the community in which I live.

The late P. T. Barnum was once asked what he thought his chances for salvation were. He said, "My friend, I have the greatest show on earth." (Laughter.) And when I saw you crowding into this room, and saw your earnest faces, I felt that you too could say that you had a very great show to accomplish anything which you undertook, whether it was an increase in your water supplies or in your salaries. (Laughter.)

This Association is comprehensive, all-embracing, takes in all of New England, I understand. I remember reading not long ago a composition that was written by a small school-boy upon the human body. He said that the human body was composed of the head, which contained the brains, if there were any. (Laughter.) The thorax, which contained the heart and the lungs; and the abdomen which contained the vowels, a, e, i, o and u, and sometimes w and y. (Laughter.) Now, I won't undertake to locate all the brains or the heart of this vast Association; I suppose it is obvious that one, at least, of your guests, ought not to assign himself to that category but rather somewhere in the indefinite part, with the w's and y's; and perhaps you may choose to locate him in the lungs, which represent the wind of such a gathering as this. (Laughter.) It is a very shrewd device, sir, it shows the acumen with which you set about everything you undertake, to get a Mayor to come here to occupy the transition period between the dinner and the intellectual enjoyment which is to follow. The remarks of a Mayor are not usually profound enough to interfere in the slightest degree with digestion, and by the time he is through everybody is ready for the intellectual feast which follows.

I am much interested in the water works, have to be; everybody becomes interested when the occasion arises, as the small boy was, you know, whom the traveler found digging near a woodchuck's hole, and asked if he thought he could get him. And the boy replied, "Why, I have got to get him ; the minister, has come and there is no fresh meat in the house." (Laughter.) So I had to find out something about water works after I was elected to office, whether I would or no. During this past year we have found the water works extremely serviceable in Cambridge in taking care of the unemployed. The connection may not be obvious. (Laughter.) I will explain. We had a million and a quarter of dollars to expend to extend our means of collecting water. We are not allowed to use any other beverage in Cambridge, and so we husband this with a great deal of care. When it became apparent that there were a great many men who were out of employment and were willing to work, (at least they said they were willing to work, although it soon became clear that the number who were out of employment and the number who were willing to work was not identical.) (Laughter.) It occurred to us that some of our expenditure might as well be made at once as to be deferred until later in the year. And so we set about the construction of a high service reservoir which we had planned, and we set about filling various unwholesome "vacuums," I think they call them now, we used to call them "holes," (Laughter.) around Fresh Pond ; and Hiram had his train of cars up there, and these people went up and he worked them; and I suspect, (Hiram is pretty thrifty and fore-handed, he came from Maine,) that by judicious

adjustment of wages and of hours the City of Cambridge hasn't lost anything by the transaction. At all events we took care of many people, showing that the water works has a function which had not been thought of always before.

I am conscious of the importance of the service in which you are engaged. The conditions of municipal life are altogether different from what they were a generation ago when most of us began to be born. I doubt if there were very many water works in the country at that time ; in the large cities there were, of course. And what is true of water works is true of a very great many indispensible conditions of municipal life, of sewerage, of lighting, of transportation. You cannot get along without these things; there is not room enough in a large city for the people to sleep where they do business. And so all these conditions have changed, and have brought about a changed condition of administration, and you are an excellent illustration of the plan which is proposed by a great many people, whether it will be ultimately adopted or not, I don't know, I mean the plan of having the municipality operate what is sometimes called a "natural monopoly." It is a very short step from the municipal ownership of water works to the municipal ownership of a lighting plant, and from that to the municipal ownership of a street railway. I will not undertake to say that each of these will be ultimately adopted by all of the cities; street lighting has already been to some extent. But the question is asked, if you can run a water works, why can't you run a street lighting plant, and why can't you run a street railway? The question will be determined in the end solely on grounds of expediency, just as the water works question was determined.

We took the water works in Cambridge, I understand, twenty-nine years ago, because the private corporation was not successful in adequately supplying the citizens. The city has been. We have got to that point now, as you must have known from the officials of the city who are members of your organization, where we do not charge the municipality anything for its water; we have a large surplus with which we are either reducing the rates or are making a construction about our reservoirs for the purpose of municipal adornment. In other words, it has been shown there, as it has been shown elsewhere, that it is possible to so operate a concern of this sort that it will be profitable for the community; and the question is asked, as I said, why not a lighting plant, and why not a street railway? And so on. And I am struck, and I believe the people who advocate a plan of this sort would be struck, by the character of the men who compose your Association. I understand, of course, that many of you are professional men, men with technical training, engineers; but the superintendents and the registrars are not necessarily men with a technical training. They are honest men, it is obvious they are able men, they are men with business ability; and it is the object of every one of those men, I take it, to retain his situation. He wants to do towards the municipality just as an individual wants to do towards his clients or towards his customers. He wants to treat it fairly, he wants to give it a full equivalent for his compensation. It is for his interest to keep the standard high. And if that is the motive which operates in the water works, it very justly will be

argued the same thing will apply to other branches of the public service if they are ever taken under municipal control. And it seems to me, I repeat, as I began, that you would be a striking object lesson for anybody who is interested in municipal government. Gentlemen, I see by the seriousness of your faces that you are about ready for the intellectual feast, and I will stop. (Loud applause.)

FILTER AT THE WANNACOMET WATER WORKS, NANTUCKET, MASS.

BY

WM. F. CODD, SUPERINTENDENT.

[Read February 16th, 1894.]

The source of water supply at Nantucket, is a natural pond of about eight acres in extent, and fourteen feet in depth, having neither surface inlet nor outlet, and a very small area of shallow flowage, the shores being quite bold.

The shores and vicinity of the pond are clean, and there is no possibility of sewage contamination, there being but one house within one-half mile of the pond, and the nearest houses of the town are more than a mile distant.

The pond is fed mainly by springs, and the water has always been of very good quality, except in the autumn of some years, when we have been troubled by the growth of *Anabœna*—one of the proteges of the State Board.

In 1891, *Anabœna* appeared about July 15 and stayed with us till October and gave more trouble than ever before. So in the spring of 1892 we constructed our filter, which, as may be seen by the plan, is a circular basin about 64 feet diameter at bottom and 6 feet deep, formed by a level clay puddle bottom 1 foot thick, and an embankment of the same material, having slopes of 2 to 1 and width on top, of 3 feet. Clay puddle was made of three parts clay and one part sand.

In the center is built a circular brick collecting well, 15.25 feet interior diameter and 8 feet deep, having a dome-shaped roof, built of wooden rafters, covered with heavy laths, which were then plastered on the outside and small stones embeded in the cement plastering to make an artistic finish. The bottom is concrete—water tight.

On the bottom and inner slope of the basin was spread a layer of sand one inch thick, to prevent the moving water from coming into contact with the clay.

Then on the bottom is a layer of round and broken stones about 2 feet thick in which are imbedded four lines of 12″ vitrified pipe tees, radiating from the well, and from each branch tee lines of 4″ vitrified pipes to receive and conduct the filtered water into the well. These pipes are all laid with a slight rising grade from the well, and the joints were packed with a turn of tarred yarn, loosely put in, and each joint was well covered with gravel.

Above the broken stone is a 6-inch layer of gravel and above that the filtering sand, which was put in in three layers and each rolled with a stone roller, the depth, when finished, being from 12 to 16 inches. The surface of the sand is level and has an area of about 4,600 square feet.

The sand was obtained from the shore of the pond, close by the side of the filter and had but very little dirt in it, which was washed out before placing. The sand has rounded particles, varying in size from $\frac{1}{10}$ of an inch down, weighs when damp and packed down as in filter about 103 pounds per cubic foot and has in a given volume about 33 per cent. are voids.

The surface of the sand in filter is about 5 feet above the highest water level of pond and is about on a level with the pump cylinders. It was built when the pond was full of water and if it had been built low enough to admit of running the water from the pond into it by gravity the interest on the extra cost of construction would more than offset the cost of pumping the water into the filter, as it will probably never be used more than two months in a year. Aeration pipes were laid, one coil inside the well, and a branch extending out, inside of every vitrified pipe, under the filter bed. These were perforated with holes $\frac{3}{32}$-inch diameter and 2 feet apart. The intention being to aerate not only the filtered water, but the filter bed itself.

Pond water is pumped through a 6″ pipe onto the surface of the sand, and kept at a depth of 12 to 18 inches above the sand. It is intended to filter at the rate of five gallons per square foot per hour.

The filter during the months it is in use is always full of water, but filtration is intermittent, depending on the times of pumping from it.

Filtered water is drawn from the well by an 8-inch pipe, the pumps being about 300 feet distant.

During the year 1892, there was not a day but what the water was all right to deliver to town without filtering, but this year of 1893, the *Anabœna* were on deck again in great numbers, and we commenced using the filter on their appearance August 8. The mode of operation was to pump into and out of the filter at the same time, aerating the water the most of the time while pumping.

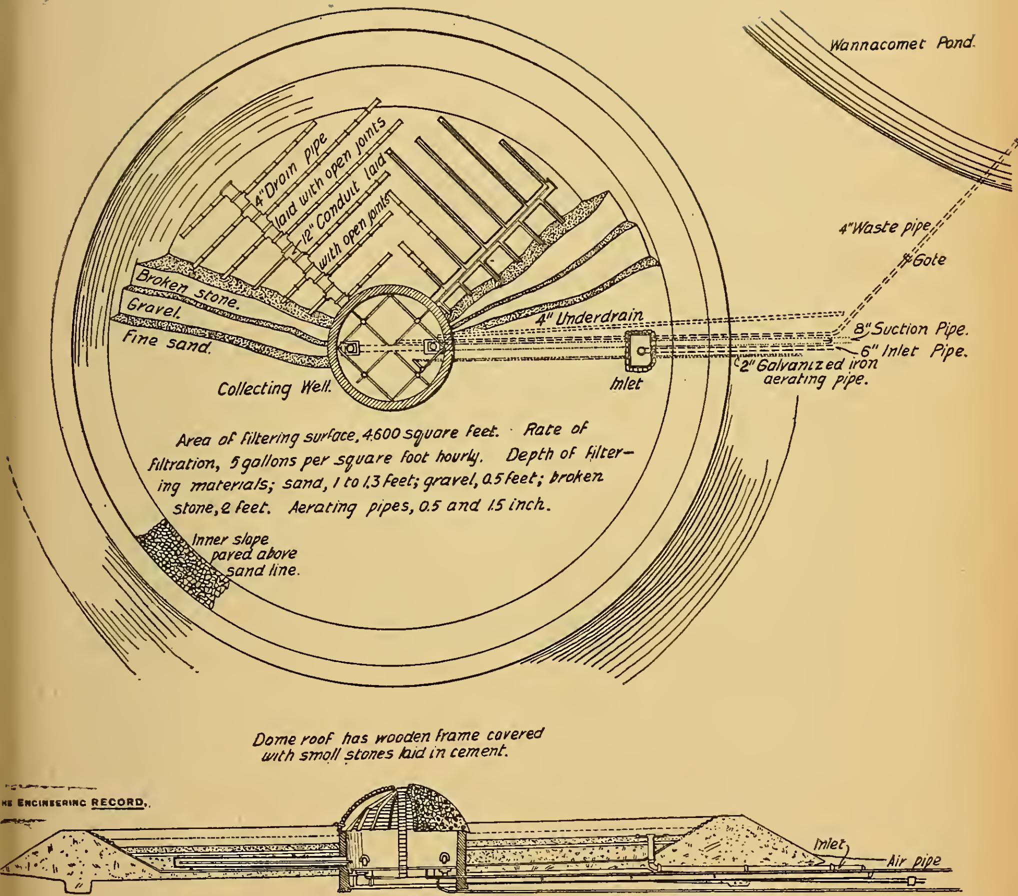
We pumped from sixty to ninety minutes at a time which filled our tank, and then shut down for three or four hours.

The first analysis of water by the State Board of Health, August 14, showed the number of *Anabœna*, in pond water to be 216,000 per 100 c. c. And in filtered water 3,600, or over 98 per cent. removed. Also almost complete removal of odor and color, both of which were strong in the pond water.

We were satisfied with the operation of our filter, but after twelve day's use complaints of odor appeared in town, the filtered water still being clear.

Two days later the surface of the sand became crusted over and almost stopped the flow of water, but it was raked over and broken up and did not clog again. After twenty-two days' use, the odor being so strong, we ceased using the filter, drew down the water and scraped the surface, removing about $\frac{1}{2}$ inch in depth, taking off as little as possible. Most of the impurities were in the top $\frac{1}{4}$ inch, though the sand was stained deeper, in some places as much as 8 or 10 inches.

We found that the air, used in aeration, in passing through the sand had seemed to gether in places, and formed little craters where it came up through the sand, instead of coming up evenly all over the bed. And probably water would find its way down these air passages without much filtering, therefore we disconnected the aeration pipes, extending under filter bed, and did not use them again, but still retained those in the well. We used the filter again September 1 for a few days, but had to give it up as the odor was so strong; and we gave the filter another examination with our constructing engineer,



FILTER AT THE WANNACOMET WATER WORKS.

and we decided that the trouble appeared after the water had been filtered and before the water reached the pump, on its way to the town, and therefore must be in the collecting well.

We now excluded sunlight from the well, ventilated the roof and aerated the water, but were troubled with odor all through September. From September 29 to October 18, we used the filter without any trouble of any kind—there being no odor—and on October 18 we discontinued its use, as the water in the pound was again all right.

Analysis of October 4 showed reduction of *Anabæna* from 96,800 to 3,800, and color from 0.25 to 0.15.

During the time, between August 20 and September 29, when the odor was worst, the temperature of water ranged from 74° to 62°. After September 29, it was below 60° and we believe the principal, if not the entire, cause of odor was the high temperature of water in the filter well, aggravated by heat from the sun, concentrated by the dome roof, and by warm air pumped in for aeration which was drawn from the engine room.

We propose to alter the roof, or rather build a flat, water-tight, submerged roof, perhaps leaving the dome in place. with large openings through the sides of the dome at and above water level, which will allow air to circulate freely, and the roof will keep the well in the shade.

It is proper to say that the engineer originally designed a flat roof, submerged, but when the dome was proposed, seeing no objections, he consented to its use.

We do not anticipate much trouble the next time *Anabæna* attacks us, if we can keep the water cool. There is an ice house near by from which air might be drawn if there is no danger of germs in it. Our tank is uncovered but as it so small and water stands in it but a short time in summer we do not fear much trouble from that source, though it would be better covered.

The capacity of the tank is 50,000 gallons, and our summer consumption ranges from 150,000 gallons to 220,000 gallons daily. The cost of the filter was $4,800 and it cost to operate it about $90.00.

THE FAIRHAVEN, MASS., WATER WORKS.

BY

JOSEPH K. NYE, SUPERINTENDENT,

[Read February 16th, 1894.]

In 1857 the little village of Fairhaven, situated in the extreme Southeastern portion of Massachusetts, opposite the city of New Bedford, was a thriving, prosperous whaling port. Business was more than good, profits large, and money was plenty. The town boasted a considerable number of wealthy men who gave freely to public benefits, and the solid granite wharves, fine churches and beautiful elm shaded streets, have been handed down as evidence of the prosperity of those good old times. But about this time the great army of whalers met the skirmish line of their enemy—petroleum. The battle that followed was short and it took only a few years to nearly wreck the whole village, not however, until glorious plans for public improvement had been made. Water, sewers, gas, etc., had all been in project, but all went down in the general crash. Water would however have been introduced, had it not been for one difficulty. No water could be found. The town had voted to secure the services of an engineer who should report upon the possibilities of a water supply, and weary from his tramp over dry fields and out-cropping ledges he gave it up in dispair, and reported the idea impossible. In his travels the engineer walked over the spot where now stands the handsome little Pumping Station of the Fairhaven Water Co. Where today we have twenty-six wells flowing over the top of the driven pipe of their own natural head 10,000 gallons per day each. Sometimes great results come from small happenings, and the small happening that resulted in the building of the Fairhaven Water Works was a very wet jacket on a small boy who skated into what they afterwards told him was an "air hole" in the ice on the little Naskatucket brook. The jacket was very wet, but the subsequent warming it got was sufficient to squeeze from it, with the addition of a few tears, a bountiful town supply. The "air hole" proved to be the out-cropping of a large quantity of subterranean water, and in 1893, fifteen years after the above named suffering circumstance, twenty-six 2½ inch tubes were pouring their supply to the surface.

The plant of the Fairhaven Water Works is, of course, nothing more than the usual pump and stand pipe system, but it contains some unusual engineering features that I think will be of interest to the members of this Association. The distribution consists of about fourteen miles of 12, 10, 8 and 6-inch pipe, the plan of the system represents almost exactly the wires of an ordinary toasting iron or grid. The one and one-half mile of 12-inch force main being the handle and the crossing of the 10, 8 and 6-inch representing the wires or grid.

On this pipe we have eighty-six hydrants of the Ludlow pattern, so arranged that we can get four or six fire streams on nearly every building on the system. All hydrants have extra large gate openings and none are connected smaller than a 6-inch supply pipe.

The twenty-six wells are connected into two 10-inch suction lines, running Easterly and Westerly from the station and at the middle point entering a cast iron suction chamber 4 feet in diameter and 4 feet deep. This chamber has a domed top and is connected with the main air pump to remove any collection of air that may be brought in by the water. From the chamber a 12-inch suction pipe is led out to the pump cylinders.

Side by side in our engine room we have two pumps of one a half million gallons capacity each, but of widely different design. One, a regular duplex, compound type with cylinders 12 and 20 inches with 12-inch stroke and water cylinders 12 inches and has a guaranteed duty of fory-five millon foot pounds on a thousand pounds of feed water.

The other pump is a wide departure from the usual design of machinery for a small station and consists of a regular cross compound crank and fly-wheel engine of the Corliss type, with but slight variation from the regular Corliss valve gear. The pump cylinders are placed at the back of the steam cylinders on the same piston rod. Steam cylinders are 15 and 30 inches by 18-inch stroke, both jacketed with live steam. The high pressure exhausts into a receiver placed between the high and low pressure sides which is also superheated by direct steam.

Each engine is fitted with separate surface condensers placed above the pump cylinders and forming a part of the force main.

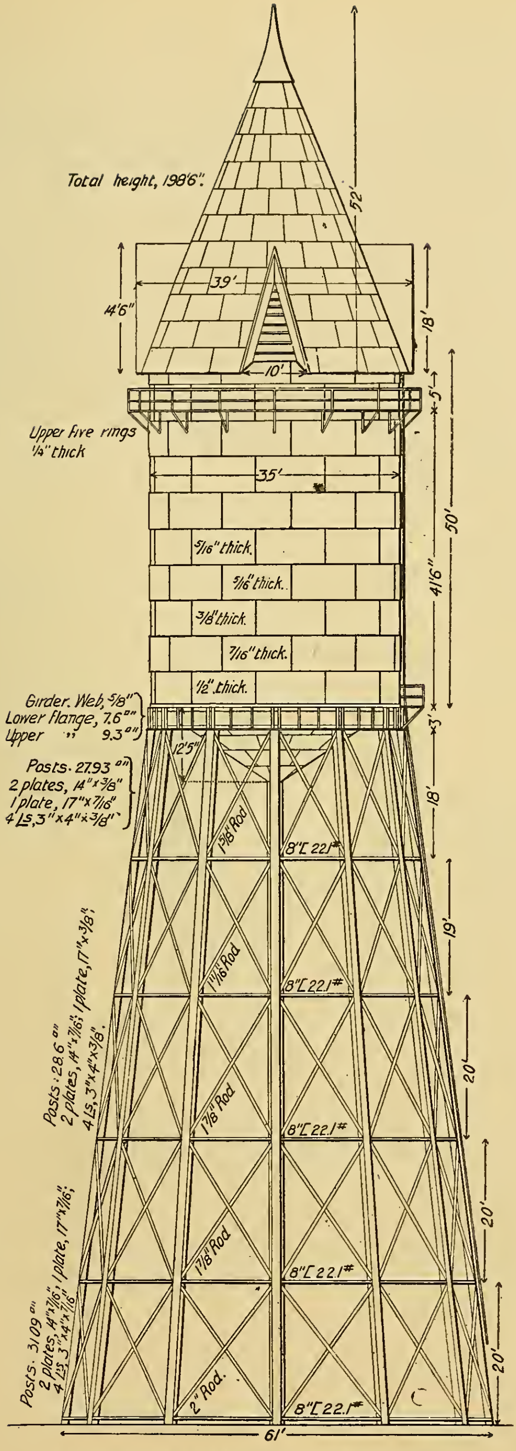
Both condensers are connected to a common air pump discharging into a hot well. The drainage from all of the cylinder jackets and superheater is discharged by means of traps into the hot well which also receives the exhaust steam from the feed pumps.

Both engines were built by the Snow Pump Co , Buffalo, N. Y.

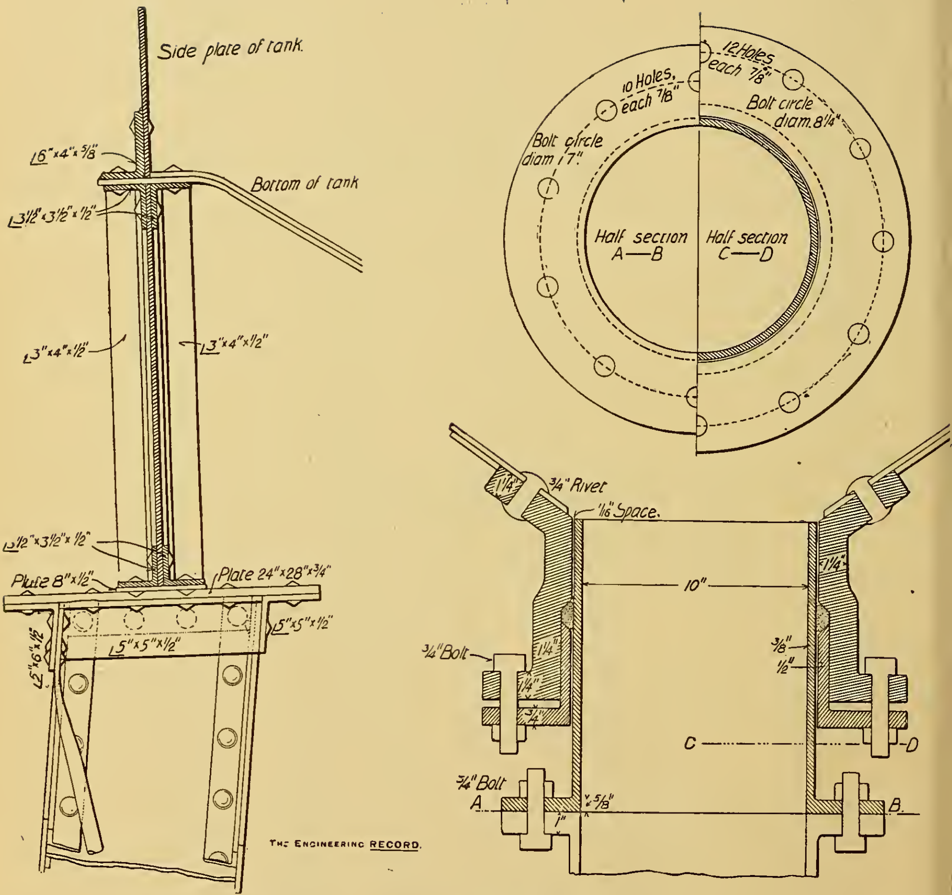
Steam is furnished by two horizontal steel boilers, 60 inches in diameter and 14 feet long, built out of two sheets running the length of the boilers and forming one-half the shell. Horizontal seams double riveted. Each boiler has 100 3-inch tubes and a 32x41 steam dome and carry a working pressure of 100 pounds.

Boilers were built by the Oil City Boiler Co., Oil City, Pa.

Directly on the force main and half way between the station and the town is placed the stand pipe and it is the portion of the work which I think contains the most novelty as there are many new features in its construction. It was designed to meet the local conditions of a level country. It was considered necessary to have the top of the stand pipe 150 feet above the ground at the highest available point, and a stand pipe of that height and 30 feet in diameter, which was the least it was thought best to make it on account of the rapidity with which it would be drawn down in case of fire, would require plates 1 3-16 inches thick in the bottom course and would cost complete with foundations $25,000 or $30,000. One 35 feet in diameter and 150 feet high



STAND PIPE, FAIRHAVEN WATER WORKS.



DETAILS OF STAND PIPE, FAIRHAVEN WATER WORKS.

would require $1\frac{3}{8}$-inch plate in the bottom course and would cost not less than $33,000 and probably $35,000 complete. It was finally decided to build a tank 35 feet in diameter and 50 feet high, and support it by a framed steel base 100 feet high. The cost of this is practically $19,000 with foundations and roof. The capacity when full is about 383,000.

The tank itself differs in no way from any ordinary well designed tank or stand pipe, except in construction of the bottom which was made in the form of an inverted cone. This was done to avoid centre supports or cross girders and transfer the strains caused by the weight of water to the outside of the tank where it was supported by the posts. The bottom plates are put in circular rings or courses with radial joints. The roundabout seams are lapped and double riveted, and the radial seams have butt joints with single color plates, and are also double riveted.

The outer course of the bottom plates are $\frac{1}{2}$-inch in thickness as are the lower course of side plates and pass under the latter and project $\frac{1}{2}$ inch beyond the angle iron which forms the connection between the sides and bottom and are riveted to it. The courses of bottom plates decrease regularly in thickness toward the center where the inlet and outlet pipe enters through a composition stuffing box, which allows for expansion and contraction or any movement of the pipe. This pipe is 12 inches in diameter, of wrought iron and secured at two points by braces to the steel frame. Its weight and that of the water it contains are supported in the ground by a heavy casting. There is a balcony around the top of the tank, and a balcony landing at the bottom near the man hole, which are constructed entirely of wrought iron.

The water supply being from an underground source, it was necessary to cover the tank to keep out the light, and a steep conical roof was constructed for the purpose. The sides of the roof make an angle of 63°—26′ with the horizon, or the rise is equal to the diameter. The covering of the roof is of $\frac{1}{8}$-inch galvanized plate, lapped and riveted on horizontal courses and riveted to the circular angle iron ribs which form the frame of the roof. There are four dormer windows with ventilating slides made with slats, which raise and lower to give access to the interior. There are also openings for ventilation about the tank under the jet, and at the extreme top by an opening under the base of the finial.

The base is 100 feet high from the coping stone of the foundation to the top of the circular girder upon which the tank rests. It is composed of twelve posts set in a circle, the diameter of which is 35 feet at the top and 61 feet at the bottom. The posts are connected with each other at points 20 feet apart by 6-inch channell iron ties, which prevent the posts from spreading and give them a lateral support at these points, thus reducing the span of the posts between points to 20 feet. The posts are also braced and counter braced at these points by 2-inch steel rods and turn buckles, to resist the overturning tendency of the wind. The ties and braces are all connected together and to the posts by a plate or gussett. The posts are in the form of a plate girder in section, with 17-inch web and 14-inch flanges made up of

plates and angle iron from $\frac{5}{16}$ to $\frac{1}{2}$-inch in thickness, the area of cross section increasing from top to bottom to provide for the increased strains due to the wind at the lower portion of the base. The top of the base is surmounted by a circular plate girder with 36-inch web and 8-inch flanges. This is designed to carry the whole strain caused by the weight of the tank and the water to the heads of the posts which are about 9 feet apart on centres at the top.

The foundation piers, one at each post, are built of rubble masonry laid in cement, and are 9 feet square at the bottom and 6 feet square on top with a coping stone 4 feet square and 15 inches deep, the top of which are hammered to receive the feet of the posts which are a plate 26x28 inches and 1 inch thick. The foundations are designed to bring a pressure of not over three tons per square foot as a maximum when the tank is full and with a wind pressure of fifty pounds per square foot. The earth is a hard pan or clayey gravel. The ground under the tank to the outside of the foundations is to be covered with coal tar concrete to prevent the washing away of the earth around or under the foundation in case of accident to the supply pipe. This stand pipe was designed in the office of M. M. Tidd, by Mr. Freeman C. Coffin, his principal asssistant, and was built by Messrs. Riter & Conley of Pittsburgh.

As everything about the system has been selected, not so much with regard to expense as utility, I think we can safely claim to have one of the best, if not the best, designed and built small systems in New England.

DISCUSSION.

Mr. FitzGerald. I should like to ask if any test was made of the yield of those wells?

Mr. Nye. We pumped from them at the rate of about 500,000 gallons a day for fourteen days; that is the only test ever made before we built the works. Since that time we have pumped 1,500,000 gallons in fifteen hours without reducing the head or flow of the wells. This was in a very wet time.

Mr. FitzGerald. In pumping 500,000 gallons a day for founteen days, how much did it lower the head in the ground.

Mr. Nye. It did not reduce the head more than three inches.

Mr. FitzGerald. Practically it did not reduce it at all.

Mr. Nye. No; it came back inside of three minutes after stopping the pump.

Mr. FitzGerald. What time in the year was it?

Mr. Nye. It was in November, and the rainfall had been very light that year.

Mr. Tidd. I think Mr. Nye has covered the entire subject. It seems to me, so far as the works are concerned, that they are a success in every way. There are some novelties about the standpipe which may be interesting to members of the Association; and I will say the credit of that design is due principally to Mr. Coffin, who was my assistant at that time, and who substantially designed it. Mr. Nye informs me he was up in it last fall during

one of the severest gales we had, and, as I understood him to say, there was positively no movement felt.

Mr. Nye. A very slight vibration inded. but a terrific noise.

Mr. Coffin. I think Mr. Nye's description ot the standpipe covers it completely. I would say it is a design the strains of which can be calculated, as well as in any structure. Although it is a novelty, I think it is designed on correct principles; and, as I say, the strains could all be figured, except there might be a question of opinion as to the wind strains on the bracing, because the posts are set in a circle, and it would be a matter of judgment how many of the sections the wind strain would come on. Of course it would come squarely on two side sections from which ever way the wind blew, and it is a matter of judgment, I should say, how much would be borne by the other sections. Two side sections would not bear anything, of course.

The first design was made with the posts of Z bar columns; but on consulting with the builders they said that at that time, it was almost impossible to obtain Z bar columns from the mills in any reasonable time, and that they cost more, and suggested the form it was put into with one plate girder; and although it is probably not quite as economical a form of material as Z bar columns, and we made them a little heavier than we would have with Z bar columns, still I think possibly it may be as well. The girder at the top is 39 inches deep. It is a circular girder, made very much like a plate girder, except that in plan it is circular, and all the weight of the water in the stand, pipe comes upon this it, and is transferred to the heads of the posts which are 9 feet apart on centres; and the girder was figured to carry that strain.

The great object, of course, in making this standpipe in this shape was the saving in cost. It was so high that a standpipe of the same cost probably would not have been more than 18 or 20 feet in diameter. I don't know as I have looked into that with sufficient care to state positively; but a standpipe of this same character, carried to the ground as a standpipe, would have cost nearly twice as much as this one did, without the foundation and without the roof. That is the advantage, in this form, namely: the saving of money. It is a novelty, of course, and I am naturally interested to see how it comes out.

Mr. Brackett. I should like to ask Mr. Coffin if there is any question in constructing a standpipe 150 feet high, of the practical use of the very heavy plates which are necessary, that is in the manufacture; having in mind, perhaps, the accident at East Providence?

Mr. Coffin. I should not want to speak positively about a thing of that kind, but it seems to me I should avoid using plates heavier than one inch, especially if all the seams were to be made lapped seams. For where three plates come together, as they do where the longitudinal joints are lapped and then a vertical joint laps on to them, there is a corner which has to be beaten down, and that has to be heated in place by some kind of a basket heater, and it seems to me it must occasion some severe strains.

Then there is another point. I don't know how the rolling might affect such thick sheets. Of course in a standpipe of that diameter there would

never be very much strain, perhaps; and it is my opinion that certainly all sheets above three-quarters of an inch should be drilled instead of punched, because the drilling would not affect the structure of the iron or steel. The tank part of the standpipe was designed to be of iron; in fact it was designed to be all of iron, except the posts, the compression members. I think, as I said before, all plates over, three-quarters of an inch should be drilled instead of punched; and, I should want to avoid using plates over one inch thick.

Mr. Nye. I would like to say the wells in our system were driven under the direction of Mr. Daniel Russell.

Mr. Tidd. This standpipe was constructed of iron, and I have always preferred iron to steel from the fact I had rather have the best quality iron than the very poorest quality of steel. I have noticed that all the standpipes in the country that have fallen have been of steel, while I know of no instance of an iron one falling.

Mr. Coggeshall. I would say one word about the appearance of this stand pipe. Most standpipes are blots on the landscape, as we all know, but this on the contrary, is a very sightly structure as we see it from New Bedford.

THE ELECTRICAL PURIFICATION OF WATER,

BY

THOMAS M. DROWN, M. D., Institute of Technology, Boston, Mass.

[Read March 14th, 1894.]

In this "Electrical Age," when a new application of electricity to every-day needs is a matter of daily experience, it does not surprise one to hear of the practical use of electricity as a purifying and disinfecting agent, particularly as we are accustomed to think of it as a force which purifies as well as destroys.

The electrical purification of water and sewage appeals to most persons therefore as a process likely to be both potent and effective. There is, moreover, to some minds a peculiar satisfaction in the contemplation of a subtile force which acts in a mysterious way, and to such minds an explanation is often an unwelcome disillusion.

Inasmuch as considerable prominence has been given in the last decade to methods of electrical purification of water and sewage, it may not be uninteresting to state briefly just how this purification is effected, and the principles on which it rests.

We may distinguish two classes of so-called electrical purification : — First, those which electrolyze water, liberating oxygen at the positive pole ; and second, those which electrolyze a solution of common salt and liberate chlorine in the same way.

The Webster process for the purification of sewage, of which a good deal was once heard, belonged mainly to the first class, although by reason of the chlorides contained in the sewage, it fell also, in part, into the second class. The oxygen liberated at the positive pole, while in the nascent state, was supposed to oxidize some organic matter, but as the pole was composed of iron plates, the oxygen was mainly consumed in oxidizing this iron, and the oxide of iron thus formed acted as a precipitating agent on the sludge in the sewage. This process was, thus, mainly one of chemical precipitation of sewage by means of oxide of iron, which was formed by a current of electricity passing through the sewage. Much was hoped for from this process, but it never passed, as far as I am aware, beyond the experimental stage.

The possibility of oxidizing organic matter on the large scale by means of nascent oxygen liberated from water by the electric current will probably never be more than a dream. Attractive as the process seems, the necessary conditions for accomplishing it could probably never be realized on a city's water supply or on its sewage.

One word in this connection about the "nascent state" of an element, of which we hear so much now-a-days. It is a well-known chemical fact that elements just liberated from combination are much more active than in their

ordinary condition. Nascent hydrogen, for instance, is a powerful reducing agent, nascent oxygen a powerful oxidizing agent — properties which are lost when these elements have assumed their molecular condition.

In some of the recent literature which I have read on the electrical purification of water, I have come across the idea that a nascent substance is one that is "fresh," in contradistinction to one that is "stale"; as if, for instance, oxygen liberated from water a minute ago would be more active than if it had been formed one hour. This is very wide of the mark — it is only at the very instant of formation that an element has enhanced powers due to its nascent or new-born condition.

The more recent systems of purification of water and sewage by electricity belong in the second class, that is, the decomposition, by electrolysis, of a solution of common salt. When a solution of salt (chloride of sodium) is decomposed by electricity, we have sodium liberated at one pole and chlorine at the other. The sodium is immediately oxidized and combines with the water present, and a solution of caustic soda results. By suitable mechanical contrivances the chlorine gas may be conducted away from the other pole as fast as liberated and collected as such. This method of making caustic soda, it may be said incidentally, is yet more or less in an experimental stage, but it seems not unlikely that the electrolytic production of caustic soda from common salt may become one of the world's great industries.

But if, instead of separating the caustic soda and chlorine from each other in this process, they are allowed to recombine, we have a complicated series of reactions resulting in the formation of various products dependent on the concentration of the liquid and its temperature. The principal product under ordinary conditions is sodium hypochlorite, variously named — chlorinated soda, chloride of soda, and in pharmacy, as Labarraque's solution. A corresponding and entirely analagous compound is the so-called chloride of lime or bleaching powder, in which lime takes the place of soda.

This, then, is the substance, sodium hypochlorite, with which we have to deal in the method of electrical purification which depends on the electrolysis of a solution of salt or sea water. When the current of electricity has, in the manner above described, formed a sufficiently concentrated solution of sodium hypochlorite, this solution is mixed with the water or sewage to be purified.

I would remark, first, that there is nothing new in the application of electricity to produce the hypochlorites, except so far as the introduction of the modern dynamo enables us to generate electricity at a much less cost than formerly, and consequently to use it economically in industrial chemical operations.

Second, there is nothing new in the use of sodium hypochlorite as a disinfectant, deodorizer and germicide.

In the very valuable Report on Disinfectants, published by the American Public Health Association in 1888, the hypochlorites were shown, experimentally, to be among the most effective of all disinfectants in their action. One per cent. of a solution of sodium hypochlorite containing six per cent. of

available chlorine, destroyed the Bacillus anthracis in two hours; two per cent. of this solution was effective in thirty minutes.

Of the corresponding lime salt, or bleaching powder, the committee reported that a solution of this substance, containing twenty-five per cent. of available chlorine, was effective in a one-per cent. solution in one or two minutes, and that a solution of one-fourth this strength would kill Bacillus anthracis and Bacillus subtilis in two hours.

The two hypochlorites of sodium and calcium were thus shown to be equally efficacious, the activity depending on the amount of hypochlorous present, or, in other words, of available chlorine.

The so-called electrical purification of water, by treating it with an electrolyzed solution of salt, is thus seen to be simply a process of disinfection by sodium hypochlorite; electricity, as such, has nothing to do with it. There is nothing peculiar in the sodium hypochlorite produced by electrolysis; it has no different properties from that made by the ordinary process of passing chlorine into a solution of caustic soda. That other compounds are formed in small amount by the action of chlorine on caustic soda is true, but it has not been shown, nor is it probable, that any one of them has as potent germicidal power as the hypochlorite.

Ozone is generally supposed to cover a multitude of sins of polution and quietly to destroy them; but we do not know much, if anything, about its germicidal power; and there is certainly no good reason for attributing any of the disinfecting action of an electrolyzed salt solution to ozone, even did we certainly know it to be present.

It is unfortunate, I think, that the advocates of this system of purification of water and sewage are not content to attribute the purifying action of the electrolyzed solution of salt solely to the hypochlorite formed. There is nothing gained by calling it "electrozone" or an "electro-saline solution," for there is nothing mysterious about its action, as these terms would lead one to suppose. Nor is it proper to speak of this system of purification in any sense as an "electrical" one.

If one were to purchase two bottles of sodium hypochlorite of identically the same composition, one prepared by a chemical process and the other by the electrolysis of a salt solution, he would not expect to find them called by different names. To call the latter an "electrical disinfectant" would be simply fantastic.

Finally, is it desirable in any case to treat a city's water supply with a powerful disinfectant like the hypochlorites? When the question is put in this bald form I cannot think it will receive the approval of engineers and sanitarians. Leaving out of consideration the difficulties and cost of disinfecting effectively and uniformly the water supply of a large city, the idea itself of chemical disinfection is repellent. Every city should jealously guard its water supply; it a sin against decency and good morals to permit the polution of drinking water by sewage and house drainage. It is a still greater wrong (not to say a foolish blunder) to permit the open polution of its drinking water streams, and then systematically to disinfect them.

In cases where a water supply has got into such a hopelessly bad condition that nothing will render it safe but disinfection by chloride of soda or chloride

of lime, it is high time, I think, to abandon the supply ; and in this opinion I feel sure most water works engineers will coincide.

DISCUSSION.

Mr. Stearns. I would like to ask Prof. Drown if he has figured the quantity of salt or hypochlorite that would have to be used in any operation of this kind?

Prof. Drown. No, but the amount could be calculated from the figures I gave. It did not seem worth while to discuss a subject of this kind on the basis of cost, since the idea of the disinfection of a water supply by chemicals is to my mind faulty in conception. Yet I think it may be said that the amount of hypochlorite necessary to thoroughly kill all the germs in a water supply of, say, fifty million or one hundred million gallons a day would be found to be very large, on the basis of the figures given by the committee of the American Public Health Association.

Prof. H. E. Smith. There is a question I would like to ask Prof. Drown. The solution which has been in use at Brewsters I have had occasion to analyze on several occasions, and it contains such a quantity of hypochlorite of sodium as corresponds to about .25 of a part of available chlorine in 1000, that is .025 per cent of available chlorine, although it is prepared by electrolizing a solution of from two to three and one-half per cent ; that is the amount of chlorine which is in this solution in available form is about one part in sixty-five or seventy of the total chlorine. Now the point which I would like to ask Prof. Drown is with regard to the application of this method to the purification of sewage, not of drinking water, for I fully agree with him that we don't want to take dirty water for this purpose, and clean it before using. Does Prof. Drown think that such a solution, of the strength which I have mentioned, and the strength which they are using there, would have any efficatious oxidizing power on the sewage, or would it act only as a disinfectant? If only as a disinfectant, of course, ultimately if the water is not greatly diluted it would undergo putrid decomposition. My question therefore is whether this amount of available chlorine would amount to anything as an oxidizing agent, or whether it is simply useful as a disinfectant to delay decomposition for a time.

Prof. Drown. I regard the electrolysis of water liberating oxygen, and the electrolysis of salt solution liberating chlorine, as both insignificant in actual power of oxidation of organic matter in water, under the conditions of ordinary practice. Some forms of easily oxidized organic matter might possibly be oxidized in this way, but to any large extent I think it has never been shown to be the case. All the attempts at treating sewage by oxydizing agents in England have shown the impracticability of this process. I regard all these chemicals of value simply as germicides, and not for the direct action on organic matter.

Mr. Herschel. I am a little disappointed by the professor casting cold water upon the idea of, or discouraging the purification of drinking water by any means that at all would promise success. The proposition, as it has been put here, is that it is a horrible thing to allow drinking water, first, to become defiled and then to purify it. But as far as the defilement of water goes, we can not practically prevent it ; that is being attended to without any

effort on our part, and being attended to only too well. There are those of us in this room who can remember when a drink of Cochituate water was a good thing to take; the rule is now it will turn your stomach. The time was when the Croton supply was considered very good drinking water; it is now barely fit to drink. And so I might go on and speak with reference to a great many other waters which at one time were very good and have become very bad. Now, the mere description in reports and catalogues, and the giving of these wonderful names to the substances, to the animalculæ and the various vegetable matters that are found in these waters, does not tend to purify them. When we classify all these bacilli and algæ, all these animals and plants, and name them, misroscope them, lithograph them, that does not purify the water. This is a practical association. It is not merely pursuing science for science's sake. Its object is not merely to know what is in the water that is harmful. I take it the object of this Association is to get rid of that stuff. Why should there be any cold water thrown on an attempt of people to purify such water? The polution of it is all the time going on, and we cannot wholly prevent it. Railroads run into the territory of the watersheds, population increases in the territory, and we cannot keep it out. You can't keep these drainage areas without getting a poluted supply, and I class the Sudbury right with them; for the Sudbury drainage area, we may say, is too densely populated to-day for giving a proper supply of water, and so is the Cochituate. That is the sum and substance of it all; that is the reason the water is not as good as it was. It is because the population is now too dense.

Now, what are you going to do about it? That used to be a political inquiry, but there is a great deal of truth in it. What are you going to do about it? That is a practical question, and it is not asked wlth any taunt in it. It is a question that will have to be answered — What are you going to do about it? You cannot take these people by the nape of the neck and kick them out of their houses and homes and depopulate the whole drainage area. Why therefore should we not welcome processes which are gone into for the purpose of purifying water? Certainly just as much argument can be made against the processes of purifying the sewage of these people, as against those for purifying the water which, in spite of all that has been done, is still not as good as it was. Why should the Professor make objections against processes for purifying water, the very thing we have all been waiting for and what we want done? I don't want these remarks of mine to be construed as arguing in tavor of the electrical purification of water, mind you, for I know very little about it. I came here to-day largely to hear what the Professor had to say, and with the hope that perhaps there was something in it. I am disappointed because from the tone of his closing remarks, it would appear that he discourages the whole idea. He says we don't want to go to purifying water; we want it pure to begin with. Well, when the millenium comes, we will have pure water, and perhaps it will stay pure; but at present, I want to hear a word of encouragement for anybody and everybody who will attempt to purify water in some practical way.

Mr. Darling. Mr. President, I am glad that Prof. Drown has hit the nail right on the head, for I think he has. I think he has come to-day and told us

just what we want to do. He says that when a water supply gets so impure it has got to be treated to make it good, it is time they looked for another source, and I think he is right about it. The only way to get pure water is to stop the impurities from going into it, and if there is a place which gets water from a source of supply where the impurities cannot be stopped from going into it, it is high time another source of supply was obtained. I suppose that in most cases the drainage of sewage into the source of supply can be stopped. We know that many cities and towns have been compelled to divert their drainage from the rivers, and I don't see any other way to prevent the trouble. I am glad, as I say, that Prof. Drown has told us the naked truth about it. He has certainly hit the nail on the head this time.

Mr. Herschel. We have here a case where bacilli and algae are to be hit on the head, not nails. The gentleman has a city for a neighbor in which some system of the sort is badly enough needed. What is Providence going to do about getting water that is fit to drink? They can't drink the water they have there; they have to buy it by the gallon if they want water fit to drink. They can't afford to abandon all their works, and why shouldn't they purify the water? And what greater objection is there to purifying it by chemical means, than there is to filtering it? It is only another method of purification.

Mr. Darling. I will answer that question. We are told that in the city of Providence, after the water has passed some four or five miles down the river, it purifies itself before it gets to the pumping station. [Laughter.] We are told that aeration of water over dams purifies it; that water purifies itself in running such a distance. Now, then, if the city of Providence will cut off the cesspools, and I understand she got rid of quite a lot of them last year, and she has been doing it for a number of years past; if she will stop the sewage from getting into the river, there won't be any trouble with the water. Or if she will go up, perhaps into Burlville, and take a new source of supply, she can get practically pure water there. The city of Boston, I expect, at some not distant day, will take her water from up in New Hampshire.

Mr. Walker. She can't do it. [Laughter.]

Mr. Darling. The city of New York is buying up the whole watershed that surrounds her supply; she is going to control the whole of it. The gentleman from New Hampshire says Boston can't do it. They have got more water up in New Hampshire than they know what to do with now; they don't use but little or it. And I may say to my friend that he has got to look out for the protection of his source of supply. The city of Manchester has got to look out for her source of supply, or else it will soon become so polluted that it will need to go somewhere else to get its water, for people are building all around it now. The only way to do is to protect our present sources, and it can be done if we will only put our shoulders to the wheel. Massachusetts is doing, through her State Board of Health, what other States have got to do. She is doing one of the grandest works that can be done, that is, stopping the pollution of water supplies. And that is what Providence has got to do, or else she must get her water from some other source.

Mr. Chace. I agree with Mr. Herschel, that it is desirable to know all we can about the purification of water, and I understand from Prof. Drown's paper that, as a practical matter, purification of water by electricity is a humbug.

SOME MEASUREMENTS OF THE FLOW OF WATER IN A 36" AND 30" COMPOUND PIPE.

BY

L. M. HASTINGS, City Engineer, Cambridge, Mass.

[Read March 14th, 1894.

The measurement of the flow of water in pipes is a matter of great interest to engineers and persons connected with water works.

Almost countless experiments have been made by American and European investigators, from M. Chezy in 1775 to the present time, to determine the ratio of the theoretical to actual discharge of pipes of different diameters, heads, and degrees of roughness, so that for ordinary conditions and sizes, the "coefficient of friction" is now pretty well determined. The opportunity to measure the flow in a compound pipe of large diameter and great length is not so easily obtained.

This may be my excuse for referring to the comparatively few measurements which I was able to make in endeavoring to determine the flow of water in the conduit pipe connecting the Stony Brook Basin with Fresh Pond, of the Cambridge Water Works.

As is probably well known to you all, Fresh Pond is situated just within the westerly limits of Cambridge, and Stony Brook, from which the additional supply is drawn, is about eight miles distant farther west and empties into Charles River.

Five thousand and ten feet of the couduit at the westerly or Stony Brook end is of 36" pipe ; the remainder 34,340 feet is of 30" pipe. the head or fall from a full basin at Stony Brook to Fresh Pond is 64 feet. The pipe follows a profile as shown on the accompanying sketch, (Fig. 1) and is unfortunately high at the pond end, rising some 28 feet above the hydraulic grade line. This rise causes a constant collection of air at the high points, and probably reduces the flow. It also seems to render the operation of the 30" gate at Fresh Pond difficult, as the large column of water standing so near the vacuum line causes a surging and commotion in the pipe at the opening or shutting of the gate.

It was in the gate house at Stony Brook that the measurements were made. The 36" pipe in passing through the wall at the gate house and opening into the effluent chamber, is enlarged to a "bell mouth" the diameter of the end or bell being 46", this dimension being obtained by dividing the diameter of the pipe (36"), by the well known factor .785, intending to give the end of the pipe, the form of the "contracted vein" of a jet of water.

The measurements were made with a "Fteley & Stearns" current meter as made by Buff & Berger of this city city. The meter was placed on the end of a rod, so that it would move on a horizontal diameter from one side of the pipe to the other, it being attached to a vertical rod or pipe, pivoted in the center, the upper end of which rod came above the floor of the Gate House.

By moving this upper end of the rod the meter at the other end could be

made to travel across the pipe in a horizontal line. The stem of the small pinion of the meter had a cam attached which at every revolution raised a light spring, which snapping back as the cam passed, made a distinct vibration, or tick, as it struck the end of a small wire, which wire was carried up through the vertical pipe to the floor above, and ended by being soldered to an empty baking power can which served as a "sounder." With this simple apparatus the blows of the "ticker" could be distinctly heard and counted from under more than 30 feet of water. By timing the number of blows per minute, the number of revolutions of the wheel could be determined and having the "rating" of the machine, the velocity of the current of water in the pipe below, could be easily ascertained.

The accompanying diagram (Fig. 2) shows the results of the measurement of velocity with different gate openings at Fresh Pond.

One interesting thing about these velocity diagrams, is the increased velocity apparent in them all, near the sides of the pipe, contrary to what is usually found to be the case. It is not easy to account for this. Possibly the bell mouth is too large and more water enters the mouth than can readily pass along the pipe, and so at the contracted part a quickening of the velocity at the sides takes place, until farther in the pipe a normal and uniform flow is established.

Another fact noted was that when these measurements were made the 30″ gate at Fresh Pond could be run down one-half its diameter, decreasing the sectional area of the opening about two-fifths without reducing the velocity of water in the pipe. It would seem that an obstacle like the gate disk did not operate to reduce the velocity in the rest of the pipe, but rather served to quicken the velocity immediately at the obstruction to compensate for the reduced area there, somewhat as is claimed for the Venturi Water Meter. The results by this measurement of the flow, agreed quite well with the computed flow assuming a rough condition of the pipe. Thus, using the formula for compound pipes as given by E. Sherman Gould, in his little book, "Practical Hydraulic Formulæ," a flow of 8,406,700 gallons per twenty-four hours is obtained, taking the large coefficient of friction.

With the Howard Murphy formula as given in Trautwine for compound pipes and the same coefficient of friction a flow of 8,865,500 gallons daily is called for. The flow as measured by the meter was 8,066,800 gallons. It seems probable that the unfortunate profile on which the pipe was laid causing air to gather and so check the flow may account somewhat for the smallness of the meter results, also it may be that the velocity curve was reduced too much at the side of the pipe beyond the point reached by the meter. A comparison with the curves found by Mr. Freeman in hose nozzles would seem to indicate that such was the case.

DISCUSSION.

Mr. Tidd. I would like to ask the gentleman if he made an experiment to ascertain at what point in closing the gate it did begin to affect the flow? There must be some point, of course, in closing the gate where it would slow the current.

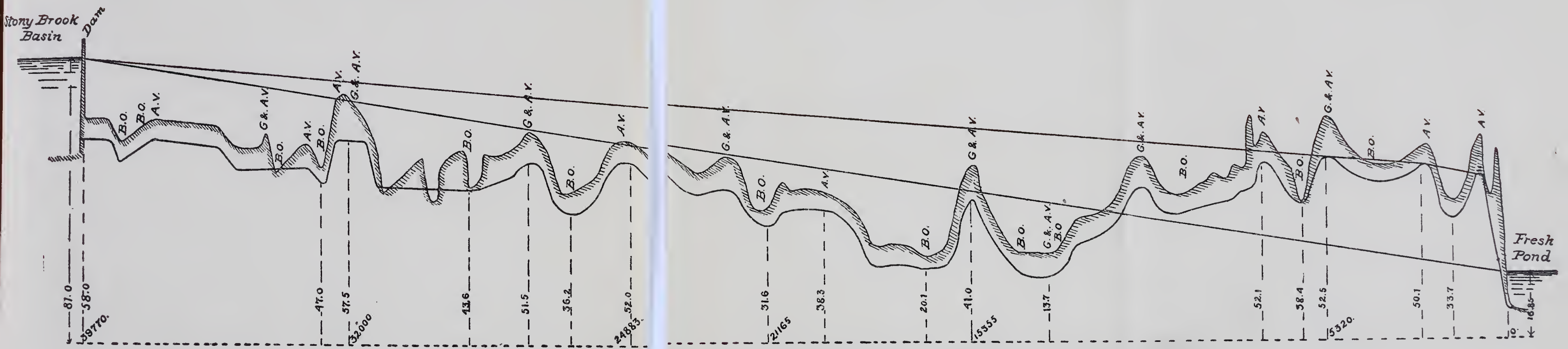


Fig 1.—Profile of Conduit, Cambridge Water Works

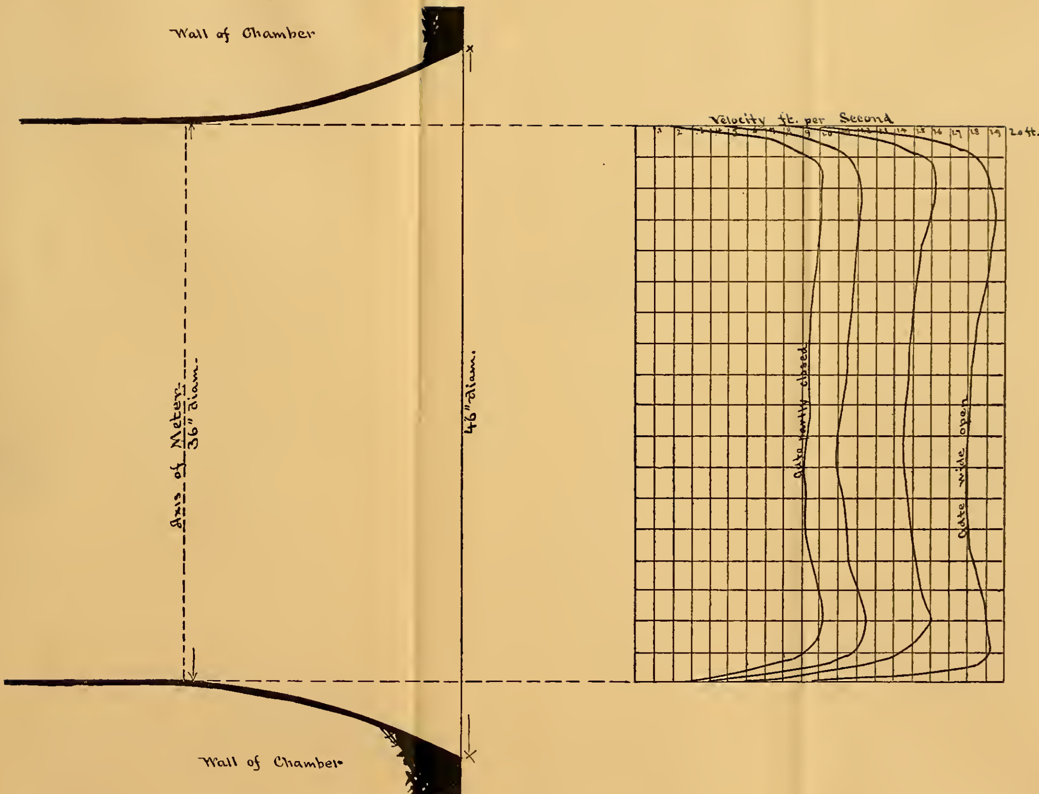

Wall of Chamber
Velocity ft. per Second
20 ft.
Axis of Meter 36" diam.
46" diam.
Gate partly closed
Gate wide open
Wall of Chamber

FIG. 2.

Mr. Hastings. I think it began soon after the disc ran below the half-way point. I was limited in the time I could use this pipe, and so I could not make as many experiments of that sort as I would have liked to, but from those I did make I concluded that was about the point beyond which we could not shut the gate without losing water.

Prof. Porter. Thinking that Mr. Hastings might show these interesting results that he obtained in the pipe, I ventured to bring a diagram of a few velocity curves obtained under different circumstances in the laboratory of the Massachusetts Institute of Technology.

They are plotted in the same general way that Mr. Hasting's curves are, that is, the varying distances of the curve from the reference line at the left show the varying velocities at corresponding points in the diameter of the orifice or pipe. These are from smaller orifices, as you see, and were obtained, not with a current meter, but with a Pitot tube, a very minute orifice connecting through a tube with a mercury gauge. What I wish to show by these diagrams is the way in which the friction of the orifice, or of the pipe, whatever it may be, affects the general shape of the curve. We might suppose that if there were no influence of friction from the pipe or the orifice we would have the same velocity across the whole diameter, and would have approximately a straight line running across from one side to the other. Now, in the case of a sharp-edged orifice in the side of a tank, (Fig. 3), an

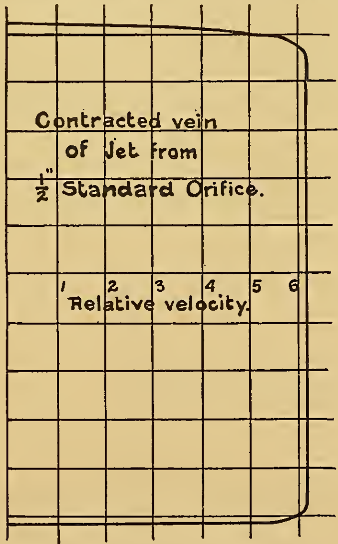


Fig. 3.

orifice which would be technically called an orifice in a thin plate, you have, it seems to me, just as little friction from the sides as you can have, and here the curve does run across nearly straight; the influence of friction is

confined to the immediate vicinity of the surface of the vein, these observations, by the way, having been taken in the contracted vein a slight distance out in front of the orifice proper.

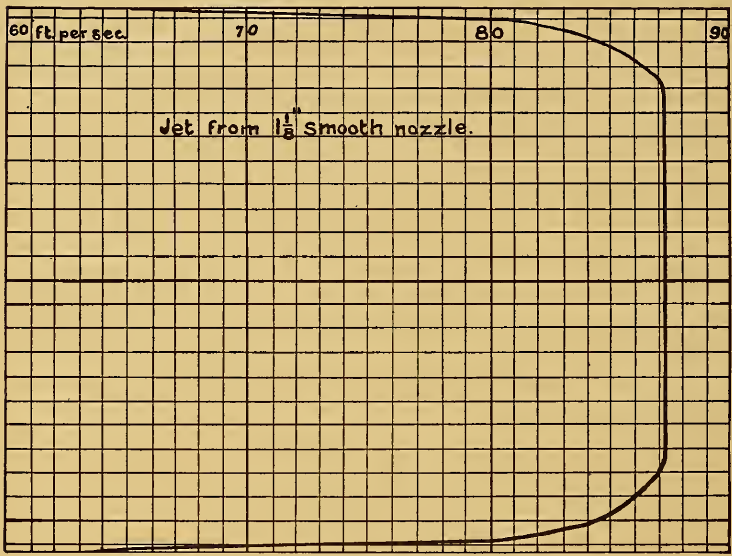


FIG. 4.

In Fig. 4 is a curve reproduced from one of Mr. Freeman's diagrams, where we have a conical nozzle. It is intermediate between a plain pipe and a standard orifice and there is a similar drawing in of the curve at the sides, under the influence of the friction, to that previously noticed.

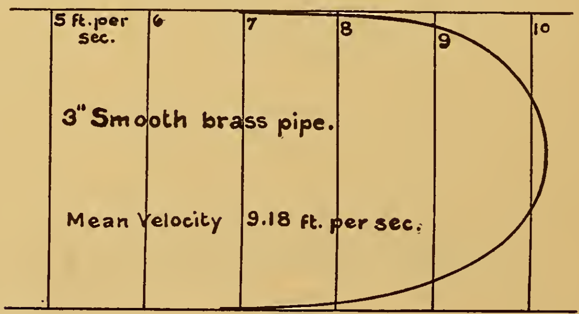


FIG. 5.

Fig. 5 is a curve which shows the way the velocity varies in the interior of a smooth brass pipe three inches in diameter, with no very great velocity

through it, the mean velocity having been 9.18 feet per second. There is a comparatively smooth curve running from the side to the centre and back on the other side.

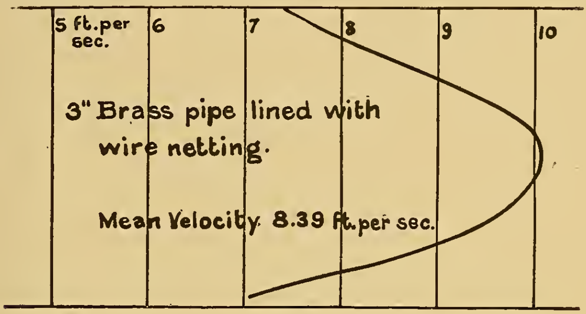


Fig. 6.

In Fig. 6 is the same thing, practically, except that the interior of the pipe was artificially roughened by lining it with wire netting. The mean velocity of the flow through the pipe was substantially the same in these two cases, but you can see a very marked change in the general shape of the curve, it being much more pointed in this case than in the former. And still another diagram of Mr. Freeman's, with water issuing from the end of an open pipe, shows a curve similar in its general shape to this. So it seems to me the general effect of friction upon the shape of the velocity curve is shown pretty well in these successive diagrams.

Mr. Coffin. I would like to ask Mr. Hastings what the distance was from Fresh Pond or Stony Brook to the highest point on the line?

Mr. Hastings. The highest point is about 2,500 feet from Fresh Pond.

Mr. Coffin. That is, it is 2,500 feet less than the total length?

Mr. Hastings. Yes.

Mr. Coffin. It seems to me the reason that the shutting of the pipe did not affect the delivery, is on account of the profile. Until the friction of the water through the gate plus the friction in the pipe for that distance for that amount of water, balances that difference in height; until that point is reached it won't make any difference in the flow. Perhaps I am not right about that, but that seemed to be an explanation to me of the fact. Mr. Hastings gave me the figures of the length of the pipe and his deliveries as he computed them, and as a matter of curiosity I computed them from two formulæ. One was Darcy's, and, roughly speaking, I got 30 feet as the head. The efficient head is 64, as I understand it, less 28—about 36 feet.

Mr. Hastings. If you consider this as a sealed pipe you get practically the whole head, as soon as it acts as a syphon.

Mr. Coffin. Did you consider it so?

Mr. Hastings. I did: yes.

Mr. Coffin. The other formula I used was $v = n\,(rs)^{1/2}$ and would give in

this case about $25\frac{1}{2}$ feet for friction head unless I made a mistake. I worked it roughly with a slide rule using the value of n as Hamilton Smith gives it in his book on hydraulics and in Darcy's formula, it would give about 30.5 feet, that is, for clean pipe.

Prof. Swain. These curves of Mr. Hastings' are very interesting to me, and it seems to me that the fact that the greater velocity occurs near the edges, may be due to the fact that the measurements were not taken far enough in the pipe to coincide with what would have been the contracted vein. I should imagine if you measured the velocity at the orifice in a thin plate, instead of measuring it in the contracted vein, as Prof. Porter did here, where the particles are all moving parallel to each other, if you should measure it right in the orifice, I should imagine the particles nearer the centre of the orifice would have greater pressure and less velocity. I should expect to find the greater velocity nearer the edge of the vein because of the pressure being less. In that way I think you could explain the fact that the greater velocity occurred near the edge, from the fact that the measurements were made nearer the orifice, one side of where the contracted vein was supposed to be.

Mr. Hastings. The measurements were made just where the contracted vein was supposed to be, 18 inches I think it was, but at any rate right at the theoretical contracted vein.

Prof. Swain. That is somewhat indefinite, isn't it, just what that curve would be?

Mr. Hastings. Yes, and that is why, I surpose, we didn't get it exactly right?

OBITUARY.

CHARLES R. DYER—Superintendent Meter Department, Water Works, Portland, Maine; sixth Vice-President of this Association for year ending June 1st, 1892. Died September 12th, 1893, aged 29 years, 3 months. Joined this Association June 11th, 1890.

THOMAS H. McLAUGHLIN—Superintendent Water Works, Texarkana, Ark. Died December 17th, 1893, aged 39 years, 1 month. Joined this Association. June 9th, 1892.

C. M. BRAINARD—Treasurer Water Works, Skowhegan, Maine. Died December 25th, 1893, aged 39 years. Joined this Association, June 12th, 1890.

WILLIAM D. TAYLOR—Superintendent Water Works, Dover, N. H. Died January 2nd, 1894, aged 45 years. Joined this Association December 14th, 1892.

WEAVER OSBORN—Member of Water Board from May, 1878, to May, 1893. Fall River, Mass. Died February 3rd, 1894, aged 78 years. Joined this Association, June 17th, 1887.

New England Water Works Association Membership Roll.

June 1, 1894.

NOTE.—The secretary requests to be advised of existing errors or changes of address from that which appears in the following list.

ACTIVE MEMBERS — RESIDENT AND NON-RESIDENT.

Abbott, Everett L.
29 Broadway, Rooms 196 and 197, New York city.

Allen, Charles A.
Civil Engineer, 44 Front street, Rooms 109 and 110, Worcester, Mass.

Allen, Charles F.
Treasurer, Hyde Park, Mass.

Allis, Solon M.
Civil Engineer, Madison, N. J.

Andrews, Frank A.
Assistant Superintendent, Nashua, N. H.

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Chief Engineer, Hartford, Conn.

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Chief Engineer, Little Falls, N. Y.

Bacot, R. C., Jr.
Superintendent Meter Department, Hoboken, N. J.

Bagnell, Richard W.
Superintendent, Plymouth, Mass.

Bailey, George I.
Superintendent, 61 State street, Albany, N. Y.

Baldwin, Charles H.
Box 2410, or 159 Franklin street, Boston, Mass.

Baldwin, Richard
Proprietor Water Works, Terryville, Conn.

Ball, Phinehas
Civil Engineer, Worcester, Mass.

Bancroft, Lewis M.
Superintendent, Reading, Mass.

Barbour, Frank A.
Civil Engineer, P. O. Box 1235, Brockton, Mass.

Barns, Everett
Superintendent, Westerly, R. I.

Barrett, Albert P.
Water Registrar, Woburn, Mass.

Barrus, George H.
Consulting Steam Engineer, 95 Milk street, Boston, Mass.

Bartlett, Charles H.
Civil Engineer, 852 Elm street, Manchester, N. H.

Bassett, Carroll Ph.
Civil Engineer, National Bank Building, Orange, N. J.

Batchelder, George E.
Registrar, Worcester, Mass.

Batcheller, Francis
Commissioner, North Brookfield, Mass.

Bates, Theodore C.
Chairman Water Commissioners, North Brookfield. Address, 29 Harvard street, Worcester, Mass.

Battles, James M.
120 Marginal, cor. Cottage street, East Boston, Mass.

Beals, Joseph E.
Superintendent, Middleboro, Mass.

Benzenberg, G. H.
City Engineer, Milwaukee, Wis.

Berkey, John A.
Pres. Electric and Water Co., Little Falls, Minn.

Bickford, Nathan B.
Superintendent Water Works, O. C. System N. Y., N. H. & H. R. R., Boston, Mass.

Billings, William R.
15 Harrison street, Taunton, Mass.

Birkinbine, Harry
Civil Engineer, Wayne, Delaware County, Penn.

Bishop, George H.
Civil Engineer, Middletown, Conn.

Bishop, Watson L.
Superintendent, Dartmouth, N. S.

Blossom, William L.
Civil Engineer, 355 Washington street, Brookline, Mass.

Boggs, Edward M.
Professor of Civil and Hydraulic Engineering, University of Arizona, Tucson, Arizona.

Bolling, Charles E.
Superintendent, Richmond, Va.

Bowers, George
City Engineer, Lowell, Mass.

Brackett, Dexter
Assistant Engineer, City Engineer's office, City Hall, Boston, Mass.

Bradley, R. H.
First Engineer, Watertown, South Dakota.

Brinsmade, Daniel S.
Engineer and Agent Ousatonic Water Co., Birmingham, Conn.

Broatch, J. C.
Superintendent, Middletown, Conn.

Brown, Arthur W. F.
Registrar, Fitchburg, Mass.

Brown, Edward H.
Superintendent and Treasurer Nevada County, N. G. R. R., Grass Valley, Cal.

Brown, J. Henry
3 Tremont street, Charlestown, Boston, Mass.

Brown, Milton A.
Superintendent, Perth Amboy, N. J.

Brownell, Ernest H.
Brown University, Providence, R. I.

Brush, Charles B.
Civil Engineer, 1 Newark street, Hoboken, N. J.

Bucknam, Geo. A. P.
Superintendent, Norwood, Mass.

Burleigh, John M.
Superintendent, South Berwick, Maine.

Burley, Harry B.
31 Milk street, Room 55, Boston, Mass.

Burnham, Albert S.
Superintendent, Revere, Mass.

Burnie, James
Superintendent, Biddeford, Me.

Burr, William H.
Professor of Civil Engineering, Columbia College, and Consulting Engineer, New York city.

Butler, J. Allen
Superintendent, Portland, Conn.

Carroll, Fred. B.
8 Dexter street, Woonsocket, R. I.

Cavanagh, John T.
Water Commissioner, Quincy, Mass.

Chace, George F.
Superintendent, Taunton, Mass.

Chadbourne, E. J.
Superintendent, Wakefield, Mass.

Chaffee, Fred. I.
Superintendent, East Providence Center, R. I.

Chandler, Charles E.
City Engineer, 161 Main street, Norwich, Conn.

Chandler, Charles F.
Professor of Chemistry, School of Mines, Columbia College, New York city.

Chase, John C.
Superintendent, Wilmington, N. C.

Childs, Wm. H.
6 Harrison street, New York city.

Clark, D. W.
President Water Company, Portland, Me.

Clark, Ezra
President and Superintendent, Hartford, Conn.

Clark, Frederick W.
Clerk, Chestnut Hill Reservoir, Boston, W. W., Brighton, Mass.

Clark, Harry W.
State Experiment Station, Lawrence, Mass.

Clarke, E. W.
95 Milk St., Room 54, Boston, Mass.

Cleaveland, W. F.
Brockton, Mass.

Coburn, Walter
19 Congress street, Lowell, Mass.

Cochran, Robert L.
Superintendent, Nahant, Mass.

Codd, William F.
Superintendent, Nantucket, Mass.

Coffin, Freeman C.
Civil and Hydraulic Engineer, 53 State street, Boston, Mass.

Coggeshall, R. C. P.
Superintendent, New Bedford, Mass.

Conant, H. W.
Superintendent, Gardner, Mass.

Conant, Whitney
Secretary Water Co., Long Branch, N. J.

Congdon, John L.
East Greenwich, R. I.

Connell, Michael A.
Superintendent, St. Hyacinthe, P. Q.

Cook, Byron I.
Superintendent, Woonsocket, R. I.

Cook, Henry A.
Superintendent, Salem, Mass.

Crandall, F. H.
Superintendent and Treasurer, Burlington, Vt.

Crandall, George K.
Civil Engineer, New London. Conn.

Crilly, P. F.
Superintendent, Woburn, Mass.

Croes, J. J. R.
Civil Engineer, 68 Broad street, Morris Building, New York city.

Crowell, George E.
President Water Works, Brattleboro, Vt.

Cunningham, W. B.
Superintendent, Trinidad, Col.

Cushing, Lucas
Assistant Superintendent, 710 Albany street, Boston, Mass.

Daboll, L. E.
Superintendent, New London, Conn.

Darling, Edwin
Pawtucket, R. I.

Davis, F. A. W.
Vice-President and Treasurer Water Co., Indianapolis, Ind.

Davis, William E.
Superintendent, Sherburne, N. Y.

Dean, Francis W.
Mechanical Engineer, Exchange Building, 53 State street, Boston, Mass.

Dean, Seth
Civil Engineer, Glenwood, Iowa.

Decker, J. H.
86 Liberty street, New York city.

Delisle, J. Olivier
Civil Engineer, 443 Dorchester street, Montreal, P. Q.

Denman, A. N.
Secretary and Manager, Des Moines, Iowa.

Dennett, Nathaniel
Superintendent, Somerville, Mass.

Denton, J. E.
Professor of Experimental Mechanics, Stevens Institute, Hoboken, N. J.

Devlin, George A.
Asst. Engineer Boston Water Works, Marlborough, Mass.

Diven, J. M.
Superintendent Water Co., Elmira, N. Y.

Doherty, Cornelius F.
Registrar, Room 15, City Hall, Boston, Mass.

Dolan, Edward
Superintendent, Troy, N. Y.

Doran, Hugh F.
Superintendent, Port Huron, Mich.

Dotten, William T.
Superintendent, Winchester, Mass.

Drake, Albert B.
Civil Engineer, 164 William street, New Bedford, Mass.

Drake, B. Frank
Water Commissioner, Lakeport, N. H.

Drake, Charles E.
Civil Engineer, New Bedford, Mass.

Drown, Thomas M.
Professor of Chemistry, Mass. Inst. of Technology, Boston, Mass.

Dunbar, E. L.
Superintendent, Bay City, Mich.

Dyer, Eben R.
Superintendent Distribution, Portland, Me.

Eardley, B. A.
Registrar Pacific Improvement Co., Pacific Grove, Monterey Co., Cal.

Eaton, Horace L.
City Engineer, Somerville, Mass.

Ellis, George A.
Civil Engineer, 158 Sherman street, Springfield, Mass.

Ellis, John W.
Woonsocket, R. I.

Ellison, W. P.
President Water Board, Newton, Mass.

Ervin, John
Secretary and Treasurer Middleton Water Supply Co., Bridgetown, N. S.

Evans, George E.
Civil Engineer, 95 Milk street, Boston, Mass.

Fales, Frank L.
Asst. Engineer Lawrence Experiment Station, Lawrence, Mass.

Fanning, John T.
Consulting Engineer, Kasota Block, Minneapolis, Minn.

Fantom, Henry T.
Rockland, Mass.

Farnham, Elmer E.
Superintendent, Box 109, Sharon, Mass.

Farnum, Loring N.
Hydraulic Engineer, 53 State street, Boston, Mass.

Felton, B. R.
City Engineer, Marlboro, Mass.

Felton, Charles R.
Asst. Engineer Sewerage Commissioners' Office, Brockton, Mass.

Fiske, Wilbur D.
Water Commissioner, Melrose, Mass. Address, 48 Arch street, Boston, Mass.

FitzGerald, Desmond
Superintendent Western Division and Resident Engineer Additional Supply Boston Water Works, Brookline, Mass.

Folwell, A. Prescott
Civil Engineer, 700 Lewis Block, Pittsburg, Pa.

Forbes, F. F.
Superintendent, Brookline, Mass.

Forbes, Murray
Manager Westmoreland Water Co., Greensburgh, Penn.

Forbes, Z. R.
Water Registrar, Brookline, Mass.

Foss, William E.
Assistant Engineer Boston Water Works, Brighton, Mass.

Freeman, John R.
Hydraulic Engineer, 31 Milk street, Room 55, Boston, Mass.

French, D. W.
Deputy Superintendent Hackensack Water Company, No. 1 Newark street, Hoboken, N. J.

Fteley, Alphonse
Chief Engineer, Aqueduct Commissioners, 213 Stewart Building, New York city.

Fuller, Frank L.
Civil Engineer, 12 Pearl street, Room 35, Boston, Mass.

Fuller, Geo. W.
Biologist, Lawrence Experiment Station, Lawrence, Mass.

Gamwell, J. H.
Treasurer Water Company, Palmer, Mass.

Gardner, L. H.
Superintendent Water Works Company, New Orleans, La.

Gerhard, William Paul
Civil Engineer, Consulting Engineer for Sanitary Works, 36 Union Square, East, New York city.

Gerrish, William B.
Superintendent, Oberlin, Ohio.

Gerry, L. L.
Civil Engineer, Room No. 1, Chase's Block, Stoneham, Mass.

Glover, Albert S.
36 Bromfield street, Room 8, Boston, Mass.

Goodier, Andrew B.
Treasurer and Superintendent, Southbridge, Mass.

Goldthwait, W. J.
Marblehead, Mass.

Goodnough, X. H.
Assistant Engineer, State Board of Health, 13 Beacon street, Boston, Mass.

Goodwin, John A.
Box 439, Madison, Me.

Gould, J. A., Jr.
Constructing Engineer, Brookline Gas Lt. Co., 1 Beacon street, Boston, Mass.

Gow, Frederick W.
Superintendent, Medford, Mass.

Gowing, E. H.
95 Milk street, Boston, Mass.

Greetham, H. W.
Local Manager, Water and Sewerage Co., Orlando, Fla.

Griffith, William E.
Secretary Water Commissioners, Cumberland, Md.

Groce, William R.
Superintendent, Rockland, Mass.

Hale, Richard A.
Principal Assistant Engineer, Essex Company, Lawrence, Mass.

Hall, Frank E.
Superintendent, Quincy, Mass.

Hamilton, William
89 Macdonnell avenue, Toronto, Ont.

Hammatt, E. A. W.
Civil Engineer, 5 Pemberton square, Boston, Mass.

Hammond, J. C., Jr.
Secretary and Treasurer, Rockville, Conn.

Hancock, Joseph C.
Superintendent, Springfield, Mass.

Harbach, Wm. F.
Water Commissioner, Newton Centre, Mass.

Haring, James S.
Civil Engineer, Suffern, Rockland Co., N. Y.

Harrington, Geo. W.
Wakefield, Mass.

Harrington, John L.
316 Pearl street, Cambridge, Mass.

Harris, D. A.
Superintendent, New Britain, Conn.

Harris, John
21 Cherry street, Waltham, Mass.

Hart, Edward W.
General Manager Water Works, Council Bluffs, Iowa.

Hartwell, David A.
City Engineer, Fitchburg, Mass.

Haskell, John C.
Superintendent, Lynn, Mass.

Hastings, L. M.
City Engineer, Cambridge, Mass.

Hastings, V. C.
Superintendent, Concord, N. H.

Hathaway, A. R.
Registrar, Springfield, Mass.

Hathaway, James H.
Registrar, New Bedford, Mass.

Hawes, Louis
Civil Engineer, 75 State street, Boston, Mass.

Hawes, William M.
Fall River, Mass.

Hayes, Ansel G.
Assistant Superintendent, Box 323, Middleboro, Mass.

Hazen, Allen
Chemist, Lawrence Experiment Station, Lawrence, Mass.

Heald, Simpson C.
Civil Engineer, 48 Congress street, Boston, Mass.

Heermans, Harry C.
Superintendent, Corning, N. Y.

Henderson, Wilson
Superintendent, Peterborough, Ontario, Canada.

Hering, Rudolph
Civil and Sanitary Engineer, 277 Pearl street, New York city.

Herschel, Clemens
Hydraulic Engineer, 2 Wall street, Room 66, New York city.

Hicks, R. S.
Secretary, Stafford Springs, Conn. Box 543.

Higgins, James H.
Supt. Meter Department, City Hall, Providence, R. I.

Hill, William R.
Chief Engineer, Syracuse, N. Y.

Holden, Horace G.
Superintendent, Nashua, N. H.

Holman, M. L.
Water Commissioner, 3744 Finney avenue, St. Louis, Mo.

How, J. C.
4½ Arlington street, Haverhill, Mass.

Hunking, Arthur W.
Care of Philadelphia Mutual Fire Insurance Co., 644 Drexel Building, Philadelphia, Penn.

Huntington, James A.
Registrar, Haverhill, Mass.

Hyde, Horatio N.
Superintendent, Newtonville, Mass.

Inman, A. W.
Superintendent Water Supply Co., Massillon, Ohio.

Jackson, Daniel D.
Water Analyst Boston Water Works, Newtonville, Mass.

Jackson, William
City Engineer, City Hall, Boston, Mass.

Johnson, William S.
Sanitary Engineer, Department of Health, 40 Clinton street, Brooklyn, N. Y.

Jones, A. J.
New Brunswick, N. J.

Jones, James A.
Registrar, Stoneham, Mass.

Jones, R. A.
Civil Engineer, Spokane Falls, Washington.

Keating, E. H.
City Engineer, Toronto, Ontario, Canada.

Kempton, David B.
Water Commissioner, New Bedford, Mass.

Kenney, Joseph L.
Superintendent, Lewiston, Me.

Kent, E. W.
Civil Engineer, Woonsocket, R. I.

Kent, Willard
Civil Engineer, Woonsocket, R. I.

Kieran, Patrick
Superintendent, Fall River, Mass.

Kimball, George A.
Civil Engineer, Room 1102, Exchange Building, 53 State street, Boston, Mass.

Kingman, Horace
Superintendent, Brockton, Mass.

Kinnicut, Leonard P.
77 Elm street, Worcester, Mass.

Knapp, Louis H.
Assistant Superintendent and Engineer, Dept. Public Works Bureau of Water, 280 Linwood avenue, Buffalo, N. Y.

Koch, Harry G.
Superintendent Castle Creek Water Co., Aspen, Colorado.

Kuehn, Jacob L.
Superintendent, York, Penn.

Laforest, J. O. Alfred
Deputy Superintendent, Montreal, Quebec.

Laing, W. H.
Superintendent Water Co., Racine, Wisconsin.

Landon, H. C.
Civil Engineer, care of Div. Eng. N. Y. State Canals, Rochester, N. Y.

Lansing, Edward T. E.
Civil Engineer, Little Falls, N. Y.

Lawton, Perry
Civil Engineer, 39 Washington street, Quincy, Mass.

Lea, R. S.
Instructor Mathematics and Drawing, McGill University, Montreal, P. Q.

Learned, Wilbur F.
Assistant Engineer, Boston Water Works, Watertown, Mass.

Leckie, R. G. E.
Constructing Engineer, Middleton, N. S.

Lockwood, Joseph A.
Superintendent, Yonkers, N. Y.

Lovell, Thomas C.
Superintendent. Office 104 River street, Fitchburg, Mass.

Lowe, H. H.
Superintendent, Clinton, Mass.

Lusk, James L.
Capt. Corps of Engineers, U. S. A., in charge of Water Supply U. S. Military Academy, West Point, N. Y.

Luther, William J.
Superintendent and Registrar, Attleboro, Mass.

Macnair, John.
Member Water Board, Lynn, Mass.

Mann, Thomas W.
Civil Engineer, Holyoke, Mass.

Marion, J. A.
Civil Engineer, Montreal, P. Q.

Martin, A. E.
Superintendent, South Framingham, Mass.

Martin, Cyrus B.
Treasurer Water Company, Norwich, N. Y.

Martine, Alfred H.
Consulting Engineer, Middlesborough, W. W., Kentucky.

Maxcy, Josiah S.
Treasurer, Gardiner, Me.

McAllister, Willis E.
Superintendent, Calais, Me.

McClintock, W. E.
Civil Engineer, Smith Building, 15 Court Square, Boston, Mass.

McConnell, B. D.
154 Greene avenue, Cote St. Antoine, Quebec.

McKenzie, Theodore H.
Engineer State Board of Health, Southington, Conn.

McNally, William
Registrar, City Hall, Marlboro, Mass.

Merritt, D. S.
Engineer and Superintendent Water Works, Tarrytown, N. Y.

Mills, Frank H.
Civil Engineer, Woonsocket, R. I.

Mirick, George L.
Civil Engineer, 49 Glen avenue, Malden, Mass.

Molis, William
Superintendent, Muscatine, Iowa.

Moore, J. L.
Superintendent, Lancaster, N. H.

Morse, Charles W.
Haverhill, Mass.

Morse, James W.
Superintendent, Natick, Mass.

Murdoch, Gilbert
Chief Engineer and Superintendent, St. John, N. B.

Nason, William E.
Superintendent, Franklin, Mass.

Naylor, Thomas
Superintendent, Maynard, Mass.

Nettleton, Charles H.
Treasurer and Superintendent, Birmingham, Conn.

Nevons, Hiram
Superintendent, Cambridge, Mass.

Newhall, John B.
Engineer and Superintendent, Crystal Water Co., Stapleton, Staten Island.

Nichols, Edward C.
Water Commissioner, Lock Box 56, Reading, Mass.

Nichols, Thomas P.
Member Water Board, 11 Prospect street, Lynn, Mass.

Northrop, Frank L.
Superintendent, Milford, Mass.

Noyes, Albert F.
Assistant Chief Engineer State Board of Health, 13 Beacon street, Boston, Mass.

Nye, George H.
Civil Engineer, New Bedford, Mass.

Nye, Joseph K.
Fairhaven, Mass.

Paine, C. W.
Civil Engineer, Room 314, Third Floor, City Hall, Cleveland, Ohio.

Paret, Milnor P.
Civil Engineer, of firm of Paret and Farquhar, Room 53, Manufacturers Record Building, Baltimore, Md.

Parks, Charles F.
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General Manager Water Works, Box 305, Jerseyville, Ill.

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Associate Professor Hydraulic Engineering, Mass. Inst. of Technology, Boston, Mass.

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Rice, L. Fredk.
Architect and Civil Engineer, 125 Milk street, Boston, Mass.

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Water Registrar, Fall River, Mass.

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Rotch, William
Civil Engineer, Room 742, Exchange Building, 53 State street, Boston, Mass.

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Sedgwick, William T.
Professor of Biology, Mass. Inst. of Technology, Boston, Mass.

Selfe, Joseph E.
Wellesley, Mass.

Shedd, Edward W.
Civil Engineer, 10 Hermitage lane, Worcester, Mass.

Shedd, J. Herbert
City Engineer, City Hall, Providence, R. I.

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Sherman, William B.
Mechanical Engineer, Box 379, Providence, R. I.

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Superintendent and Secretary, Holliston, Mass.

Shirreffs, Reuben
Consulting Engineer, 1103 Main street, Richmond, Va.

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Prof. Chemistry, Yale Medical School. Address, 430 George street, New Haven, Conn.

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Swain, George F.
Professor of Civil Engineering, Mass. Inst. of Technology, Boston, Mass.

Swan, Charles H.
Civil and Sanitary Engineer, 110 Boylston street, Boston, Mass.

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Assistant Clerk, Water Board Office, Boston, Mass.

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Southern Pines, Moore Co., N. C.

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Tidd, M. M.
Hydraulic Engineer, 10 Tremont street, Boston, Mass.

Tingley, R. H.
Civil Engineer, 75 Westminster street, Providence, R. I.

Tinkham, S. Everett
Assistant Engineer, Engineering Department, City Hall, Boston, Mass.

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Civil Engineer, 89 State street, Boston, Mass.

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Biologist, Boston Water Works, Brighton, Mass.

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Mechanical Engineer, 131 South Third street, Philadelphia, Penn.

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